Step 1: Problem Segregation

1. The problem is segregated into two different models, one using the Cov3D and other one using the Conv2d + RNN
2. Ran 24 experiments on Conv3d and 18 experiments using Conv2d + RNN with different Hyper parameters

---

Step 2: Tool Usage

1. Because there were 42 experiments overall and it was hard to track, I used Mlflow tracking which helped me track the experiments also compare the overall results
2. Here is the link for more details https://www.mlflow.org/docs/latest/tracking.html

---

Step 3: Directory Structure

```
+---Conv2d_RNN
|   |   Neural_Nets_Project_Conv2D_RNN.ipynb
|   |
|   \---workspace
|       |   experiments-conv2d-CNN.json
|       |
|       \---best_model
|               model-00012-0.02995-0.99095-1.40236-0.77000.h5
|
\---Conv3d
    |   Neural_Nets_Project_Conv3D.ipynb
    |
    \---workspace
        |   experiments-conv3d-from-13th.json
        |   experiments-conv3d-from-22nd.json
        |   experiments-conv3d.json
        |
        \---best_model
                model-00047-0.33229-0.99698-1.63650-0.74000.h5
```

Contains 2 ipynb files for respective models, /workspace has the /best_model in .h5 file and also /workspace has experiment configurations in .json file

Step 4: Experiments Details

Key considerations:

- Keeping Batch size to 16, because of **ResourceExhaustedError**

Experiment with conv2d + RNN Model

Following are the parameters are considered to run experiments

1. **minimumLearningRate**: lower bound on the learning rate.
2. **learningRateFactor**: 0.1, 0.15, 0.2 (factor by which the learning rate will be reduced. new_lr = lr * factor)
3. **optimizer**: SGD, Adagrad, Adam
4. **numberOfEpochs**: 20, 50

I have externalized the experiments, details are in **experiments-conv2d-RNN.json**, which is specific to the model with Conv2d + RNN to segregate the experiments. More details in appendix section

Experiment with conv3d

Following are the parameters are considered to run experiments

1. **minimumLearningRate**: lower bound on the learning rate.
2. **learningRateFactor**: 0.1, 0.15, 0.2 (factor by which the learning rate will be reduced. new_lr = lr * factor)
3. **optimizer**: SGD, Adagrad, Adam
4. **numberOfEpochs**: 20, 50

I have externalized the experiments, details are in **experiments-conv3d.json**, which is specific to models with Conv3D and MaxPooling3D to segregate the experiments. More details in appendix section

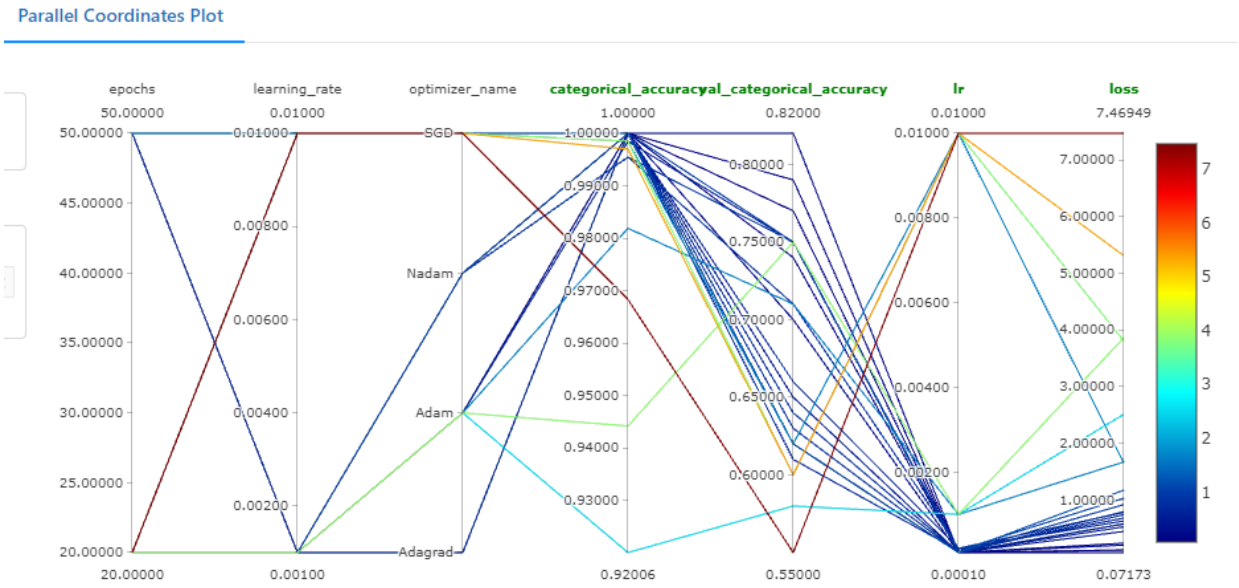
Due to disk space limitations, I was unable to run completely at once. After cleaning up, I resumed from the 13th experiment and the 22nd. That's why there are 3 json files

Step 5: Experiment Outcomes using Conv3d

Overall Runs

			Metrics >			Parameters >		
	Duration	Models	categorical_accu	loss	lr	epochs	initial_epoch	learning_rate
	31.1min	keras	1	0.072	1.000e-4	50	0	0.001
	31.3min	keras	1	0.238	1.000e-4	50	0	0.001
	12.4min	keras	0.995	0.78	2.000e-4	20	0	0.001
	12.4min	keras	1	1.033	1.500e-4	20	0	0.001
	12.2min	keras	0.995	0.919	1.000e-4	20	0	0.001
	30.3min	keras	1	0.118	1.000e-4	50	0	0.001
	30.7min	keras	1	0.204	1.000e-4	50	0	0.001
	30.7min	keras	0.998	0.578	1.000e-4	50	0	0.001
	12.4min	keras	0.92	2.512	0.001	20	0	0.001
	12.4min	keras	0.982	1.671	0.001	20	0	0.001
	12.4min	keras	0.944	3.862	0.001	20	0	0.001
	30.4min	keras	1	0.445	1.000e-4	50	0	0.001
	30.4min	keras	1	0.526	1.000e-4	50	0	0.001
	30.0min	keras	1	0.576	1.000e-4	50	0	0.001
	12.2min	keras	1	0.629	2.000e-4	20	0	0.001
	12.2min	keras	1	0.681	1.500e-4	20	0	0.001
	12.3min	keras	1	0.74	1.000e-4	20	0	0.001
	30.2min	keras	1	0.794	1.000e-4	50	0	0.01
	30.2min	keras	1	1.174	1.000e-4	50	0	0.01
	30.2min	keras	0.998	1.659	0.01	50	0	0.01
	12.2min	keras	0.998	3.806	0.01	20	0	0.01
	12.2min	keras	0.997	5.31	0.01	20	0	0.01
	14.7min	keras	0.968	7.469	0.01	20	0	0.01

Observations



From the parallel coordinate plot, we can see that higher number of epochs (50), lower learning rate (0.001),lower lr factor, Optimizer Nadam & Adagrad performed very well.

Best vs Worst with respect to Loss

Comparing 2 Runs

Run ID:	08320b3a556f4101ab84f6eed0fa25ac	227ed6b1549f4ccea3bf8f91ca23c297
Start Time:	2021-11-18 07:30:57	2021-11-17 17:08:22

Parameters

class_weight	None	None
epochs	50	20
epsilon	1e-07	
initial_epoch	0	0
learning_rate	0.001	0.01
max_queue_size	10	10
num_layers	21	21
optimizer_name	Nadam	SGD
shuffle	True	True
steps_per_epoch	42	42
validation_steps	7	7

Metrics

categorical_accuracy	1	0.968
loss	0.072	7.469
lr	1.000e-4	0.01
val_categorical_accuracy	0.77	0.55
val_loss	1.197	8.863

Best vs Worst with respect to Validation categorical accuracy

Comparing 2 Runs

Run ID:	49f8b24f949648c3a47a68a167b9280b	227ed6b1549f4ccea3bf8f91ca23c297
Start Time:	2021-11-18 06:59:19	2021-11-17 17:08:22

Parameters

epochs	50	20
epsilon	1e-07	
initial_epoch	0	0
learning_rate	0.001	0.01
max_queue_size	10	10
num_layers	21	21
optimizer_name	Nadam	SGD
shuffle	True	True
steps_per_epoch	42	42
validation_steps	7	7
workers	1	1

Metrics

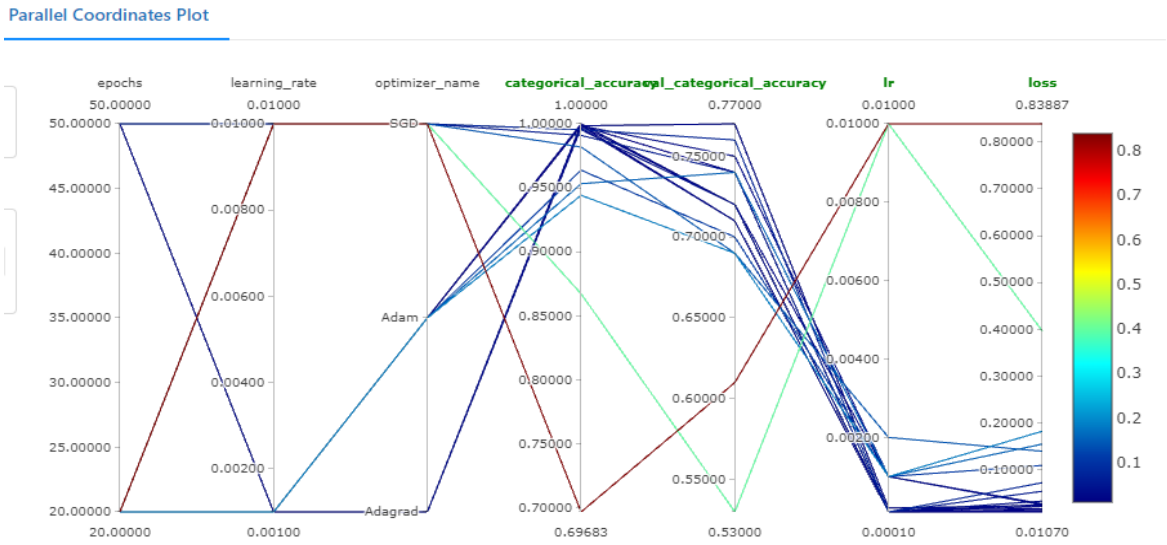
categorical_accuracy	1	0.968
loss	0.238	7.469
lr	1.000e-4	0.01
val_categorical_accuracy	0.82	0.55
val_loss	0.921	8.863

Step 6: Experiment Outcomes using Conv2d+RNN

Overall Runs

		Metrics >			Parameters >		
Duration	Models	categorical_accu	loss	lr	epochs	initial_epoch	learning_rate
23.0min	keras	0.998	0.011	1.000e-4	50	0	0.001
23.5min	keras	0.998	0.016	1.000e-4	50	0	0.001
23.3min	keras	1	0.012	1.000e-4	50	0	0.001
9.4min	keras	0.964	0.11	0.001	20	0	0.001
9.5min	keras	0.953	0.155	0.001	20	0	0.001
9.4min	keras	0.944	0.183	0.001	20	0	0.001
23.0min	keras	0.998	0.017	2.000e-4	50	0	0.001
23.1min	keras	1	0.022	1.000e-4	50	0	0.001
22.9min	keras	0.997	0.026	1.000e-4	50	0	0.001
9.5min	keras	0.998	0.025	2.000e-4	20	0	0.001
9.4min	keras	0.998	0.026	0.001	20	0	0.001
9.4min	keras	0.998	0.028	0.001	20	0	0.001
23.6min	keras	0.995	0.034	1.000e-4	50	0	0.01
22.7min	keras	0.991	0.055	1.000e-4	50	0	0.01
21.7min	keras	0.995	0.073	1.000e-4	50	0	0.01
8.7min	keras	0.982	0.14	0.002	20	0	0.01
9.0min	keras	0.867	0.397	0.01	20	0	0.01
9.0min	keras	0.697	0.839	0.01	20	0	0.01

Observations



From the parallel coordinate plot, we can see that higher number of epochs (50), lower learning rate (0.001),lower lr factor, Optimizer Adam & Adagrad performed very well.

Best vs Worst with respect to Loss

Comparing 2 Runs

Run ID:	34e49311f5db44d3939b22c4ca0d6907	41dfa13cd95543d6be97469030c4db45
Start Time:	2021-11-18 20:02:54	2021-11-19 00:35:33

Parameters

epochs	20	50
epsilon		1e-07
initial_epoch	0	0
learning_rate	0.01	0.001
max_queue_size	10	10
num_layers	4	4
optimizer_name	SGD	Adam
shuffle	True	True
steps_per_epoch	42	42
validation_freq	1	1
validation_steps	7	7

Metrics

categorical_accuracy	0.697	0.998
loss	0.839	0.011
lr	0.01	1.000e-4
val_categorical_accuracy	0.61	0.71
val_loss	1.014	1.99

Best vs Worst with respect to Validation categorical accuracy

Comparing 2 Runs

Run ID:	ec6056b2426546778ae0cea5ba483d6d	34e49311f5db44d3939b22c4ca0d6907
Start Time:	2021-11-18 23:48:10	2021-11-18 20:02:54

Parameters

batch_size	None	None
class_weight	None	None
epochs	50	20
epsilon	1e-07	
initial_epoch	0	0
learning_rate	0.001	0.01
max_queue_size	10	10
num_layers	4	4
optimizer_name	Adam	SGD
steps_per_epoch	42	42
validation_steps	7	7

Metrics

categorical_accuracy	1	0.697
loss	0.012	0.839
lr	1.000e-4	0.01
val_categorical_accuracy	0.72	0.61
val_loss	1.629	1.014

~***~

Appendix

experiments-conv3d.json


```
{
   "parameters": [
      {
         "learningRateFactor": "0.1",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "20",
         "optimizer": "SGD",
         "title": "Experiment - 1"
      },
      {
         "learningRateFactor": "0.15",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "20",
         "optimizer": "SGD",
         "title": "Experiment - 2"
      },
      {
         "learningRateFactor": "0.20",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "20",
         "optimizer": "SGD",
         "title": "Experiment - 3"
      },
      {
         "learningRateFactor": "0.1",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "50",
         "optimizer": "SGD",
         "title": "Experiment - 4"
      },
      {
         "learningRateFactor": "0.15",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "50",
         "optimizer": "SGD",
         "title": "Experiment - 5"
      },
      {
         "learningRateFactor": "0.20",
         "minimumLearningRate": "0.0001",
         "numberOfEpochs": "50",
```

```
    "optimizer": "SGD",
    "title": "Experiment - 6"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 7"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 8"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 9"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 10"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 11"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 12"
  },
  {
```

```
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adam",
    "title": "Experiment - 13"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adam",
    "title": "Experiment - 14"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adam",
    "title": "Experiment - 15"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adam",
    "title": "Experiment - 16"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adam",
    "title": "Experiment - 17"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adam",
    "title": "Experiment - 18"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Nadam",
```

```
        "title": "Experiment - 19"
      },
      {
        "learningRateFactor": "0.15",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "20",
        "optimizer": "Nadam",
        "title": "Experiment - 20"
      },
      {
        "learningRateFactor": "0.20",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "20",
        "optimizer": "Nadam",
        "title": "Experiment - 21"
      },
      {
        "learningRateFactor": "0.1",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "Nadam",
        "title": "Experiment - 22"
      },
      {
        "learningRateFactor": "0.15",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "Nadam",
        "title": "Experiment - 23"
      },
      {
        "learningRateFactor": "0.20",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "Nadam",
        "title": "Experiment - 24"
      }
    ]
}
```


---

experiments-conv2d-CNN.json


```
{
```

```
"parameters": [
    {
        "learningRateFactor": "0.1",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "20",
        "optimizer": "SGD",
        "title": "Experiment - 1"
    },
    {
        "learningRateFactor": "0.15",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "20",
        "optimizer": "SGD",
        "title": "Experiment - 2"
    },
    {
        "learningRateFactor": "0.20",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "20",
        "optimizer": "SGD",
        "title": "Experiment - 3"
    },
    {
        "learningRateFactor": "0.1",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "SGD",
        "title": "Experiment - 4"
    },
    {
        "learningRateFactor": "0.15",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "SGD",
        "title": "Experiment - 5"
    },
    {
        "learningRateFactor": "0.20",
        "minimumLearningRate": "0.0001",
        "numberOfEpochs": "50",
        "optimizer": "SGD",
        "title": "Experiment - 6"
    },
    {
        "learningRateFactor": "0.1",
        "minimumLearningRate": "0.0001",
```

```
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 7"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 8"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adagrad",
    "title": "Experiment - 9"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 10"
  },
  {
    "learningRateFactor": "0.15",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 11"
  },
  {
    "learningRateFactor": "0.20",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "50",
    "optimizer": "Adagrad",
    "title": "Experiment - 12"
  },
  {
    "learningRateFactor": "0.1",
    "minimumLearningRate": "0.0001",
    "numberOfEpochs": "20",
    "optimizer": "Adam",
    "title": "Experiment - 13"
  },
```

```
    {
      "learningRateFactor": "0.15",
      "minimumLearningRate": "0.0001",
      "numberOfEpochs": "20",
      "optimizer": "Adam",
      "title": "Experiment - 14"
    },
    {
      "learningRateFactor": "0.20",
      "minimumLearningRate": "0.0001",
      "numberOfEpochs": "20",
      "optimizer": "Adam",
      "title": "Experiment - 15"
    },
    {
      "learningRateFactor": "0.1",
      "minimumLearningRate": "0.0001",
      "numberOfEpochs": "50",
      "optimizer": "Adam",
      "title": "Experiment - 16"
    },
    {
      "learningRateFactor": "0.15",
      "minimumLearningRate": "0.0001",
      "numberOfEpochs": "50",
      "optimizer": "Adam",
      "title": "Experiment - 17"
    },
    {
      "learningRateFactor": "0.20",
      "minimumLearningRate": "0.0001",
      "numberOfEpochs": "50",
      "optimizer": "Adam",
      "title": "Experiment - 18"
    }
  ]
}
```