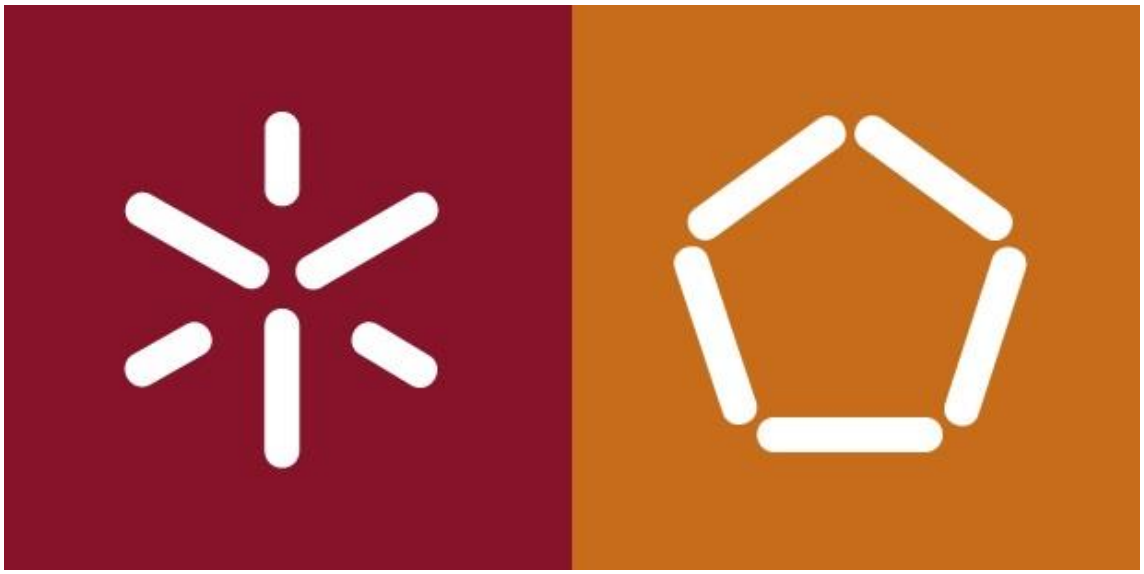
Universidade do Minho

Departamento de Informática
Mestrado Integrado em Engenharia Informática



Perfil de Machine Learning: Fundamentos e Aplicações
Classificadores e Sistemas Conexionistas
Trabalho Prático nº 5

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Parte 1

No primeiro exercício desta ficha era pretendido que fosse implementada uma rede LSTM com o objetivo de compreender a forma como se comportam estas redes. Foi observado através de múltiplas execuções, variando o número de épocas, timesteps e features, a performance que este tipo de redes recorrentes apresentam. Tratando-se o problema em questão de tentar fazer com a rede prevê-se números aleatórios com base no conhecimento de escolhas de números aleatórios em sequência, as execuções feitas demonstram alguma instabilidade de resultados como seria de prever pois tratando de sequências aleatórias tornam-se também imprevisíveis. Deixo aqui apenas um log de uma das execuções:

```
timesteps = 10
features = 25
```

Utilizando estes valores para timesteps e features obtiveram-se os seguintes resultados:

```
PS C:\Users\Bosch\Desktop\Mestrado\MLFA\2º Semestre\CSC\TP5> & C:/Users/Bosch/Anaconda3/envs/CSC/python.exe "c:/Users/Bosch/Desktop/Mestrado/MLFA/2º Semest
re/CSC/TP5/ex1.py"
2020-03-25 22:15:44.463405: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:15:46.651068: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library nvcuda.dll
2020-03-25 22:15:46.686305: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1555] Found device 0 with properties:
pciBusID: 0000:01:00.0 name: GeForce GTX 1660 Ti computeCapability: 7.5
coreClock: 1.59GHz coreCount: 24 deviceMemorySize: 6.00GiB deviceMemoryBandwidth: 268.26GiB/s
2020-03-25 22:15:46.700576: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:15:46.713791: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cublas64_10.dll
2020-03-25 22:15:46.728292: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cufft64_10.dll
2020-03-25 22:15:46.740475: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library curand64_10.dll
2020-03-25 22:15:46.754914: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusolver64_10.dll
2020-03-25 22:15:46.767277: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusparse64_10.dll
2020-03-25 22:15:46.788781: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudnn64_7.dll
2020-03-25 22:15:46.799227: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1697] Adding visible gpu devices: 0
2020-03-25 22:15:46.807745: I tensorflow/core/platform/cpu_feature_guard.cc:142] Your CPU supports instructions that this TensorFlow binary was not compile
d to use: AVX AVX2
2020-03-25 22:15:46.826944: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1555] Found device 0 with properties:
pciBusID: 0000:01:00.0 name: GeForce GTX 1660 Ti computeCapability: 7.5
coreClock: 1.59GHz coreCount: 24 deviceMemorySize: 6.00GiB deviceMemoryBandwidth: 268.26GiB/s
2020-03-25 22:15:46.851594: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:15:46.865228: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cublas64_10.dll
2020-03-25 22:15:46.876420: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cufft64_10.dll
2020-03-25 22:15:46.883307: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library curand64_10.dll
2020-03-25 22:15:46.895567: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusolver64_10.dll
2020-03-25 22:15:46.907058: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusparse64_10.dll
2020-03-25 22:15:46.919089: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudnn64_7.dll
2020-03-25 22:15:46.933105: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1697] Adding visible gpu devices: 0
2020-03-25 22:15:47.516756: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1096] Device interconnect StreamExecutor with strength 1 edge matrix:
2020-03-25 22:15:47.524248: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1102]      0
2020-03-25 22:15:47.536325: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1115] 0:   N
2020-03-25 22:15:47.542842: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1241] Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:
0 with 4625 MB memory) -> physical GPU (device: 0, name: GeForce GTX 1660 Ti, pci bus id: 0000:01:00.0, compute capability: 7.5)
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 10, 32)            7424
_________________________________________________________________
lstm_1 (LSTM)                (None, 10, 64)            24832
_________________________________________________________________
lstm_2 (LSTM)                (None, 128)               98816
_________________________________________________________________
dense (Dense)                (None, 25)                3225
=================================================================
Total params: 134,297
```

```
Total params: 134,297
Trainable params: 134,297
Non-trainable params: 0
_________________________________________________________________
None
2020-03-25 22:15:51.455039: I tensorflow/stream_executor/platform/
2020-03-25 22:15:51.779204: I tensorflow/stream_executor/platform/
Epoch: 0; Loss: 16.12; Accuracy: 0.00
Epoch: 1; Loss: 1.27; Accuracy: 0.00
Epoch: 2; Loss: 1.61; Accuracy: 0.00
```

```
Epoch: 98; Loss: 16.12; Accuracy: 0.00
Epoch: 99; Loss: 16.12; Accuracy: 0.00
Accuracy: 6.00
Sequence: [[18, 8, 13, 21, 19, 9, 18, 8, 6, 22]]
Expected: [13]
Predicted: [2]
```

Parte 2

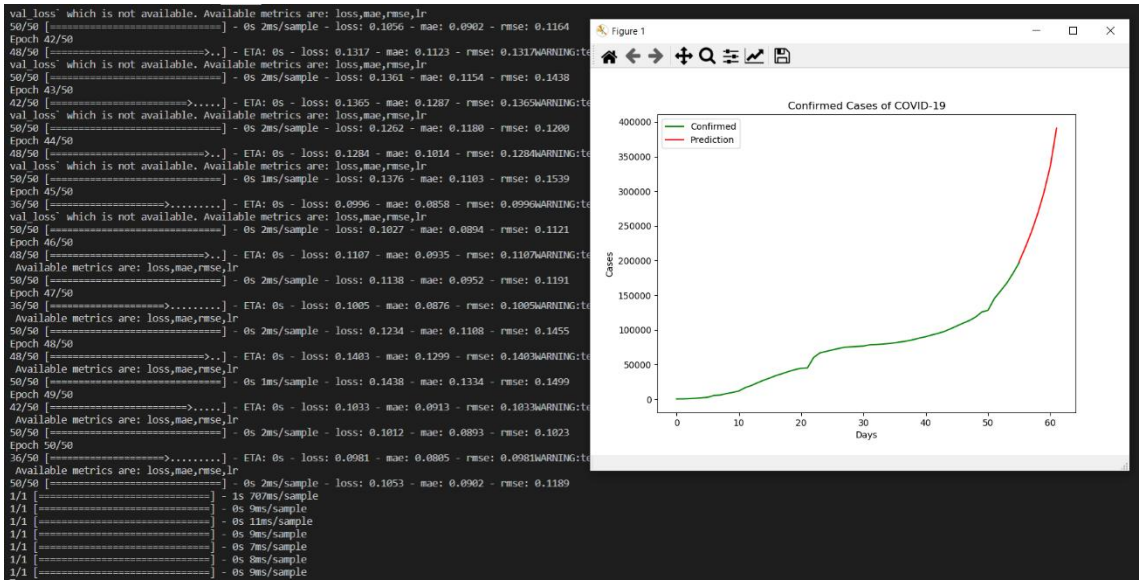
Neste segundo exercício era pretendido que fosse criada uma rede MLP ou LSTM para prever o número de casos confirmados esperados nos próximos 7 dias de COVID-19. Foi então criada uma rede LSTM e o processo foi o seguinte:

- Começar por importar e preparar o dataset dos casos confirmados até ao momento;
- Construir uma rede LSTM através da api Keras, utilizando um modelo sequencial de várias camadas incluindo, para além de LSTM's, Dense. Para função de cálculo de Loss foi utilizada a função *root mean square error* construída através do uso de funções disponibilizadas pela api Keras;
- Por fim, foi criada a função forecast que efetua as previsões e outra função para demonstrar o gráfico obtido de casos confirmados nos próximos 7 dias.

Nas imagens podemos ver uma das execuções efetuadas, vendo o gráfico de casos confirmados previsto a vermelho e a verde os do dataset:

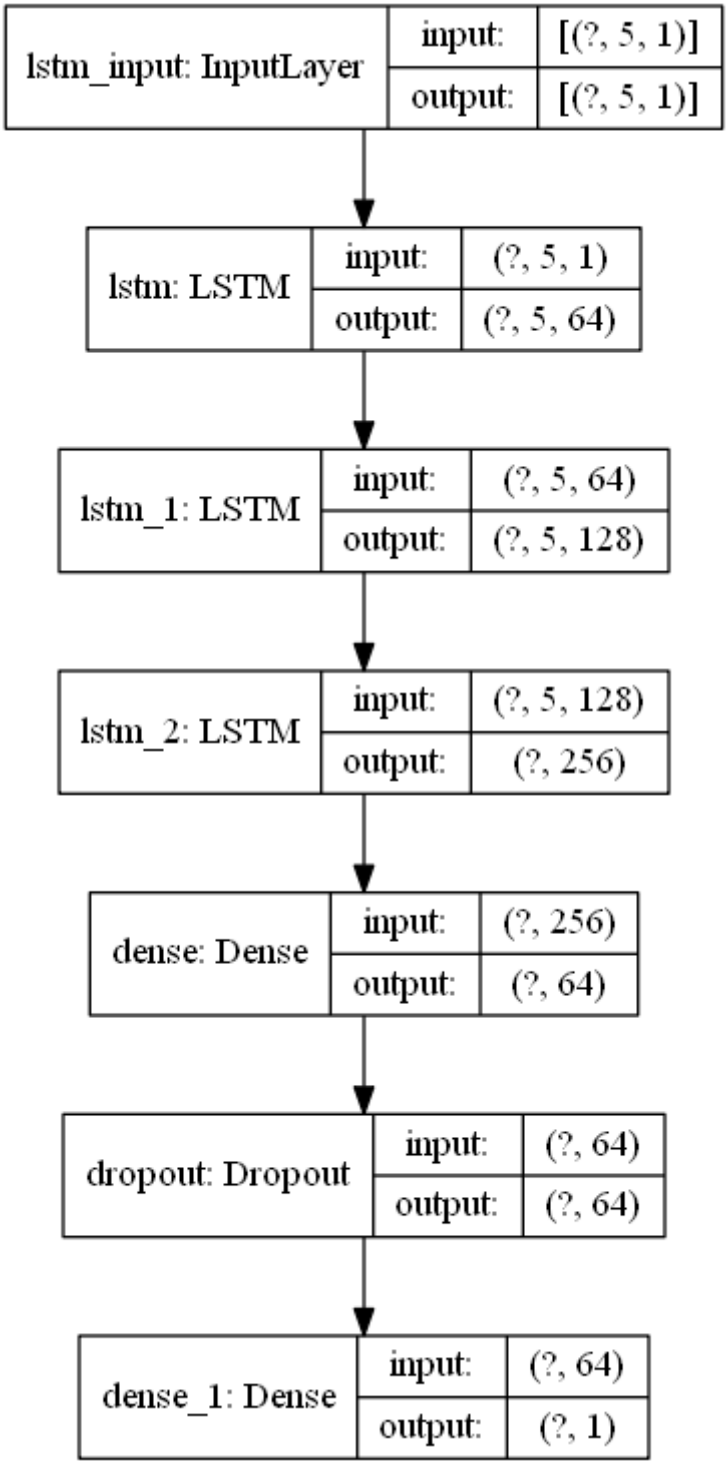
```
PS C:\Users\Bosch\Desktop\Mestrado\MLFA\2º Semestre\CSC\TP5\Ex2> & C:/Users/Bosch/Anaconda3/envs/CSC/python.exe "c:/Users/Bosch/Desktop/Mestrado/MLFA/2º Se
mestre/CSC/TP5/Ex2/ex2.py"
2020-03-25 22:33:47.408378: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:33:51.888454: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library nvcuda.dll
2020-03-25 22:33:51.922449: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1555] Found device 0 with properties:
pciBusID: 0000:01:00.0 name: GeForce GTX 1660 Ti computeCapability: 7.5
coreClock: 1.59GHz coreCount: 24 deviceMemorySize: 6.00GiB deviceMemoryBandwidth: 268.26GiB/s
2020-03-25 22:33:51.935286: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:33:51.949137: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cublas64_10.dll
2020-03-25 22:33:51.960565: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cufft64_10.dll
2020-03-25 22:33:51.969738: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library curand64_10.dll
2020-03-25 22:33:51.982737: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusolver64_10.dll
2020-03-25 22:33:51.992543: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusparse64_10.dll
2020-03-25 22:33:52.016238: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudnn64_7.dll
2020-03-25 22:33:52.023450: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1697] Adding visible gpu devices: 0
2020-03-25 22:33:52.027907: I tensorflow/core/platform/cpu_feature_guard.cc:142] Your CPU supports instructions that this TensorFlow binary was not compile
d to use: AVX AVX2
2020-03-25 22:33:52.038388: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1555] Found device 0 with properties:
pciBusID: 0000:01:00.0 name: GeForce GTX 1660 Ti computeCapability: 7.5
coreClock: 1.59GHz coreCount: 24 deviceMemorySize: 6.00GiB deviceMemoryBandwidth: 268.26GiB/s
2020-03-25 22:33:52.049946: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudart64_101.dll
2020-03-25 22:33:52.055483: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cublas64_10.dll
2020-03-25 22:33:52.061634: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cufft64_10.dll
2020-03-25 22:33:52.067185: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library curand64_10.dll
2020-03-25 22:33:52.074618: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusolver64_10.dll
2020-03-25 22:33:52.101296: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cusparse64_10.dll
2020-03-25 22:33:52.125623: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudnn64_7.dll
2020-03-25 22:33:52.135572: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1697] Adding visible gpu devices: 0
2020-03-25 22:33:52.859380: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1096] Device interconnect StreamExecutor with strength 1 edge matrix:
2020-03-25 22:33:52.866565: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1102]      0
2020-03-25 22:33:52.870175: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1115] 0:   N
2020-03-25 22:33:52.886146: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1241] Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:
0 with 4625 MB memory) -> physical GPU (device: 0, name: GeForce GTX 1660 Ti, pci bus id: 0000:01:00.0, compute capability: 7.5)
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 5, 64)             16896
_________________________________________________________________
lstm_1 (LSTM)                (None, 5, 128)            98816
_________________________________________________________________
lstm_2 (LSTM)                (None, 256)               394240
_________________________________________________________________
dense (Dense)                (None, 64)                16448
_________________________________________________________________
dropout (Dropout)            (None, 64)                0
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 5, 64)             16896
_________________________________________________________________
lstm_1 (LSTM)                (None, 5, 128)            98816
_________________________________________________________________
lstm_2 (LSTM)                (None, 256)               394240
_________________________________________________________________
dense (Dense)                (None, 64)                16448
_________________________________________________________________
dropout (Dropout)            (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 65
=================================================================
Total params: 526,465
Trainable params: 526,465
Non-trainable params: 0
_________________________________________________________________
None
Train on 50 samples
Epoch 1/50
2020-03-25 22:33:57.992041: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cublas64_10.dll
2020-03-25 22:33:58.329446: I tensorflow/stream_executor/platform/default/dso_loader.cc:44] Successfully opened dynamic library cudnn64_7.dll
48/50 [===========================>..] - ETA: 0s - loss: 0.3911 - mae: 0.3842 - rmse: 0.3911 WARNING:tensorflow:Reduce LR on plateau conditioned on metric
`val_loss` which is not available. Available metrics are: loss,mae,rmse,lr
50/50 [==============================] - 5s 98ms/sample - loss: 0.4092 - mae: 0.4025 - rmse: 0.4412
Epoch 2/50
42/50 [========================>.....] - ETA: 0s - loss: 0.2207 - mae: 0.2098 - rmse: 0.2207WARNING:tensorflow:Reduce LR on plateau conditioned on metric `
val_loss` which is not available. Available metrics are: loss,mae,rmse,lr
50/50 [==============================] - 0s 2ms/sample - loss: 0.2562 - mae: 0.2444 - rmse: 0.2857
Epoch 3/50
42/50 [========================>.....] - ETA: 0s - loss: 0.1241 - mae: 0.1108 - rmse: 0.1241WARNING:tensorflow:Reduce LR on plateau conditioned on metric `
val_loss` which is not available. Available metrics are: loss,mae,rmse,lr
50/50 [==============================] - 0s 2ms/sample - loss: 0.1222 - mae: 0.1084 - rmse: 0.1279
Epoch 4/50
30/50 [================>.............] - ETA: 0s - loss: 0.6343 - mae: 0.5757 - rmse: 0.6343WARNING:tensorflow:Reduce LR on plateau conditioned on metric `
val_loss` which is not available. Available metrics are: loss,mae,rmse,lr
50/50 [==============================] - 0s 2ms/sample - loss: 0.4694 - mae: 0.4296 - rmse: 0.4698
```



Como se pode ver todo os objetivos desta ficha foram alcançados, com a compreensão das redes recorrentes, mais propriamente com a utilização das mesmas através de LSTM disponibilizadas pela api Keras.

Na imagem seguinte podemos ver o modelo que foi construído mais detalhadamente:


lstm_input: InputLayer
input: [(?, 5, 1)]
output: [(?, 5, 1)]
lstm: LSTM
input: (?, 5, 1)
output: (?, 5, 64)
lstm_1: LSTM
input: (?, 5, 64)
output: (?, 5, 128)
lstm_2: LSTM
input: (?, 5, 128)
output: (?, 256)
dense: Dense
input: (?, 256)
output: (?, 64)
dropout: Dropout
input: (?, 64)
output: (?, 64)
dense_1: Dense
input: (?, 64)
output: (?, 1)