

**Evaluating Occurrence of a *Ramanujan Lakshmana Super Magic Square* via Deep Learning techniques with Keras**

# **What is a Ramanujan Lakshmana Super Magic Square?**

Let us first explain what is Ramanujan Square and then later what is Ramanujan Lakshmana Super Magic Square.

|  |  |  |  |
| --- | --- | --- | --- |
| **R1C1** | **R1C2** | **R1C3** | **R1C4** |
| **R2C1** | **R2C2** | **R2C3** | **R2C4** |
| **R3C1** | **R3C2** | **R3C3** | **R3C4** |
| **R4C1** | **R4C2** | **R4C3** | **R4C4** |

## **Ramanujan Square:**

Let us consider a square with its cells as given alongside.

For this square to be a ***Ramanujan Magic Square*** for the birth date *‘dd/mm/ccyy’*, (according your region, you can change the format, let us consider Indian Format for simplicity), Assign values as follows:

* **R1C1** = dd (day), **R1C2** = mm (month), **R1C3** = cc (century), **R1C4** = yy (year)

and fill the remaining cells satisfying the following rules/properties:

***Property i:*** The sum of the numbers of every cell in *each row*, *column* and *diagonal* as well as that of the *four corners* should be a *constant*

*i.e., [RnC1 + RnC2+ RnC3+ RnC4] = [R1Cn + R2Cn+ R3Cn+ R4Cn] = [R1C1 + R2C2+ R3C3+ R4C4] = [R1C4 + R2C3+ R3C2+ R4C1]*

*= [R1C1 + R4C1+ R1C4+ R4C4] = constant*

***Property ii:*** The sum of the numbers in each *2x2 boxes* should be equal to same *constant* exceptthe *[R1C2, R1C3, R2C2, R2C3]* and *[R3C2, R3C3, R4C2, R4C3]* boxes

|  |  |  |  |
| --- | --- | --- | --- |
| **R1C1** | **R1C2** | **R1C3** | **R1C4** |
| **R2C1** | **R2C2** | **R2C3** | **R2C4** |
| **R3C1** | **R3C2** | **R3C3** | **R3C4** |
| **R4C1** | **R4C2** | **R4C3** | **R4C4** |

|  |  |  |  |
| --- | --- | --- | --- |
| R1C1 | R1C2 | R1C3 | R1C4 |
| R2C1 | **R2C2** | **R2C3** | R2C4 |
| R3C1 | **R3C2** | **R3C3** | R3C4 |
| R4C1 | R4C2 | R4C3 | R4C4 |

|  |  |  |  |
| --- | --- | --- | --- |
| R1C1 | R1C2 | R1C3 | R1C4 |
| **R2C1** | **R2C2** | **R2C3** | **R2C4** |
| **R3C1** | **R3C2** | **R3C3** | **R3C4** |
| R4C1 | R4C2 | R4C3 | R4C4 |

*For example*, in the squares shown below, the cells highlighted with the same colour correspond to a box

***Property iii:*** All the numbers of the square must belong to the set of natural numbers *N* and should be unique with the exception of the first row (in case of repetition in the birth date itself)

|  |  |  |  |
| --- | --- | --- | --- |
| *dd* | *mm* | *cc* | *yy* |
| *aa* | *cc + yy - aa* | *-mm - yy + aa + 2 \* bb* | *dd + 2 \* mm + yy - aa - 2 \* bb* |
| *bb* | *dd + mm - bb* | *mm + yy - bb* | *-mm + cc + bb* |
| *mm + cc + yy - aa - bb* | *-mm + aa + bb* | *dd + mm + yy - aa - bb* | *-yy + aa + bb* |

On solving for such a square in accordance with the above properties using *linear algebra*, we obtain the values of each cell of the *Ramanujan Square* as given below:

where ‘*aa’* and ‘*bb’* are variants to be adjusted to fulfil the above *property iii*

**Note:**

1. *aa* cannot exceed *cc + yy*; since *R2C2 = cc + yy – aa*
2. *bb* cannot exceed *dd + mm* and *mm + yy*; since *R3C2 = dd + mm – bb* and *R3C3 = mm + yy – bb*

|  |  |  |  |
| --- | --- | --- | --- |
| **22** | **12** | **18** | **87** |
| **88** | **17** | **09** | **25** |
| **10** | **24** | **89** | **16** |
| **19** | **86** | **23** | **11** |

With the calculation of above formula, Ramanujan birth day square is given aside:

This Ramanujan Square is an extraordinary mathematical pattern, where every column, row, diagonal, the four corners, and even adjacent 2x2 squares sum to a consistent total of 139 on the left-hand side of the table. ***But this excludes the specially highlighted light blue and dark blue squares where Total is not 139*** solving a challenge ***Ramanujan himself couldn’t address!.***

To address this, I came with following approach.

## **Ramanujan Lakshmana Magical Square:**

|  |  |  |  |
| --- | --- | --- | --- |
| R1C1 | **R1C2** | **R1C3** | R1C4 |
| R2C1 | **R2C2** | **R2C3** | R2C4 |
| R3C1 | **R3C2** | **R3C3** | R3C4 |
| R4C1 | **R4C2** | **R4C3** | R4C4 |

If ***bb =***  then all adjacent *2x2 boxes* will satisfy *property ii* including the *[R1C2, R1C3, R2C2, R2C3]* and *[R3C2, R3C3, R4C2, R4C3]* boxes.

This square is a ‘***Ramanujan Lakshmana Super Magic Square’***.

## **Who will have a Super Magic Square?**

For a *Super Magic Square*, *bb* ***=*** . Consequently, the table becomes

|  |  |  |  |
| --- | --- | --- | --- |
| *dd* | *mm* | *cc* | *yy* |
| *aa* | *cc + yy - aa* | *dd - cc +aa* | *mm +cc -aa* |
|  |  |  |  |
|  |  |  |  |

***Corollary****:* In order for the third row to comply with *property iii*, *dd + mm + cc + yy* must be ***even number***and must be greater than *dd*, *mm*, *cc* and *yy*.

Let *dd*, *mm*, *cc* take the highest possible values for this century i.e. *dd=31*, *mm=12*, *cc=20*. Now we will find yy to suit the corollary.

*=> 31.5 +( yy/2) > {31, 12, 20, yy} => 31.5 > (yy/2)* => *yy* < 63.

|  |  |  |  |
| --- | --- | --- | --- |
| **22** | **12** | **20** | **24** |
| **9** | **35** | **11** | **23** |
| **19** | **15** | **17** | **27** |
| **28** | **16** | **30** | **4** |

Hence to obtain *Super Magic Square* for this century, it is necessary to have ***yy <63***.

A close-up of a newspaper

Description automatically generated

My findings are published in Trinity Paper Dec 2020. Current year has super magic square on Ramanujan Birthdate as given above. You can explore and verify this fascinating mathematical creation interactively through a configurable format of date to the region specific application available at  <https://lksmangai.github.io/AngularBirthDate/BirthDateMagicSquare/> to find magic squares based on anyone's birth date. For those interested in delving deeper into the algorithms and formulas behind generating magical square tables, please check out  <https://github.com/lksmangai/DeepLearning/blob/master/article%20ramanujan%20square.pdf>

Now let us know, how to apply deep learning to predict whether magic square and super magic square using Keras.

## Keras:

***Keras*** is a powerful high-level *neural network API* and an *easy-to-use,* *free, open source* Python library for developing and evaluating *deep learning models* in just a few lines of code. It wraps the efficient numerical computation libraries – Theano, TensorFlow, and CNTK and is designed to run on the CPU as well as the GPU.

## ‘Deep Learning’ steps:

## Python Program to illustrate the use of Deep Learning to predict the Occurrence of a Ramanujan Lakshmana Super Magic Square for given dates:

1. **Load historical data**

# for loading data Let us take first week of 2019  
start\_date = date(2019, 1, 1)  
end\_date = date(2019, 1, 7)  
  
# load magic square data for weeks  
dataset = find\_squares\_dates(start\_date, end\_date)  
  
# range of the input columns in the dataset  
xColumns = numpy.r\_[0:5, 8:9]  
  
# range of the output columns in the dataset  
# let us only evaluate magic or special for testing purpose.  
yColumns = numpy.r\_[16:18]  
# otherwise un comment the following  
# yColumns = numpy.r\_[5:8, 9:21]  
  
# split into input and output variables  
X\_input = dataset[:, xColumns]  
Y\_output = dataset[:, yColumns]

1. **Create training and testing data**

# seed is initialized to get same results  
seed = 5  
numpy.random.seed(seed)  
  
# split the data into training (70%) and testing (30%)  
(X\_train, X\_test, Y\_train, Y\_test) = train\_test\_split(X\_input, Y\_output, test\_size=0.30, random\_state=seed)

1. **Define Keras model**

# create the model  
model = Sequential()  
# add the first hidden layer of input columns with 8 nodes, also called a Neuron or Perceptron  
model.add(Dense(8, input\_dim=xColumns.size, activation='relu', kernel\_initializer='uniform'))  
# add the second hidden layer with 6 nodes  
model.add(Dense(6, activation='relu', kernel\_initializer='uniform'))  
# finally add output columns  
model.add(Dense(yColumns.size, activation='sigmoid', kernel\_initializer='uniform'))

1. **Compile Keras model**

# compile the model  
# loss function : maximum likelihood, error between 2 probability distributions measured using cross-entropy  
# optimizer: The Adam optimization algorithm, an extension to stochastic gradient descent to increase the learning rate  
model.compile(loss='binary\_crossentropy', optimizer='adam', metrics=['accuracy'])

1. **Train model on training data**

# fit the model  
# training occurs over epochs(One pass through all rows in training dataset) and each epoch is split into batches  
# verbose is to display the training sessions in console  
model.fit(X\_train, Y\_train, validation\_data=(X\_test, Y\_test), epochs=10, batch\_size=5, verbose=1)

1. **Evaluate model on test data**

# finally evaluate the model  
scores = model.evaluate(X\_test, Y\_test)  
print("Accuracy: %.2f%%" % (scores[1]\*100))

1. **Guess predictions via trained model**

# initalize to randomly generate 100 dates  
predict\_date\_variables: numpy.ndarray = numpy.ndarray((0, 6), dtype=int)  
# randomly generate 100 dates  
*for* myrandom *in* range(99):  
 myRandArray = numpy.array([1+get\_random\_number(27), 1+get\_random\_number(11), 18+get\_random\_number(2),  
 1+get\_random\_number(98), 1+get\_random\_number(98), 1+get\_random\_number(98)],dtype=int)  
 predict\_date\_variables = numpy.concatenate((predict\_date\_variables, [myRandArray]), axis=0)  
# guess predictions for given days at a time  
predictions = model.predict(predict\_date\_variables)  
pointer = 0  
*for* each\_day *in* predict\_date\_variables:  
 print("date: %d / %d / %d%d " %(each\_day[0], each\_day[1], each\_day[2], each\_day[3]))  
 print("Magic Availability: %.2f%% Super Magic Availability: %.2f%%"  
 %(predictions[pointer][0]\*100, predictions[pointer][0]\*100) )

**Full Source Code is copied below for the reference:**

# organize imports  
*from* keras.models *import* Sequential  
*from* keras.layers *import* Dense  
*from* sklearn.model\_selection *import* train\_test\_split  
*from* datetime *import* timedelta, date  
*import* numpy  
  
#Square basic class  
*class* Square:  
   
 *def \_\_init\_\_*(self):  
 self.dd=0  
 self.mm=0  
 self.cc=0  
 self.yy=0  
 self.aa=0  
 self.bb=0  
 self.n1=0  
 self.n2 = 0  
 self.n3 = 0  
 self.n4 = 0  
 self.n5 = 0  
 self.n6 = 0  
 self.n7 = 0  
 self.n8 = 0  
 self.n9 = 0  
 self.n10 = 0  
  
# Collection of Squares Class  
*class* SquareCollection:  
 *def \_\_init\_\_*(self):  
 self.magic: bool = *False* self.special:bool = *False* self.negatives:int = 0  
 self.zeros:int = 0  
 self.repetition:int = 0  
 self.numbers = []  
   
 # funtion to print the square  
 *def \_\_str\_\_*(self):  
 *return* "{ repetition: " + self.repetition.\_\_str\_\_() + "; zeros: " + self.zeros.\_\_str\_\_() + "; magic: " \  
 + self.magic.\_\_str\_\_() + "; special: " + self.special.\_\_str\_\_()+ "; numbers: " + \  
 self.numbers.\_\_str\_\_() + " }"  
  
 # function to convert elements to array  
 *def* toArray(self,*oneSquare*:Square):  
 self.numbers = [*oneSquare*.dd, *oneSquare*.mm, *oneSquare*.cc, *oneSquare*.yy, *oneSquare*.aa, *oneSquare*.n1,  
 *oneSquare*.n2, *oneSquare*.n3, *oneSquare*.bb, *oneSquare*.n4, *oneSquare*.n5, *oneSquare*.n6,  
 *oneSquare*.n7, *oneSquare*.n8, *oneSquare*.n9, *oneSquare*.n10]  
  
 self.negatives = 0  
 self.zeros = 0  
 self.repetition = 0  
 #compare each element whether negative or zero or repetition  
 *for* num *in* range(4, 16, 1):  
 *if* (self.numbers[num] < 0):  
 self.negatives += 1  
 *if* (self.numbers[num] == 0):  
 self.zeros += 1  
 *for* comp *in* range(0, 4, 1):  
 *if* (self.numbers[num] == self.numbers[comp]):  
 self.repetition += 1  
 *for* comp *in* range(num + 1, 16, 1):  
 *if* (self.numbers[num] == self.numbers[comp]):  
 self.repetition += 1  
 self.magic = (self.repetition == 0) *and* (self.zeros <= 1) *and* (self.negatives==0)  
 self.special = (2 \* *oneSquare*.bb) == (*oneSquare*.dd + *oneSquare*.mm - *oneSquare*.cc + *oneSquare*.yy) \  
 *and* (self.magic)  
  
   
 myspecial = numpy.array([self.magic, self.special, self.repetition, self.zeros, self.negatives], dtype=int)  
 mynumbers = numpy.array(self.numbers, dtype=int)  
 myarray = numpy.concatenate([mynumbers, myspecial])  
 *return* myarray  
  
  
# finding square algorithm  
*def* find\_squares(*oneSquare*:Square, *SquareCollections*):  
 *oneSquare*.aa=0  
 *oneSquare*.bb=0  
 *for oneSquare*.aa *in* range(120):  
 *oneSquare*.bb = 0  
 *for oneSquare*.bb *in* range(50):  
 *oneSquare*.n1 = *oneSquare*.cc + *oneSquare*.yy - *oneSquare*.aa  
 *oneSquare*.n2 = -*oneSquare*.mm - *oneSquare*.yy + *oneSquare*.aa + 2 \* *oneSquare*.bb  
 *oneSquare*.n3 = *oneSquare*.dd + 2 \* *oneSquare*.mm + *oneSquare*.yy - *oneSquare*.aa - 2 \* *oneSquare*.bb  
 *oneSquare*.n4 = *oneSquare*.dd + *oneSquare*.mm - *oneSquare*.bb  
 *oneSquare*.n5 = *oneSquare*.mm + *oneSquare*.yy - *oneSquare*.bb  
 *oneSquare*.n6 = -*oneSquare*.mm + *oneSquare*.cc + *oneSquare*.bb  
 *oneSquare*.n7 = *oneSquare*.mm + *oneSquare*.cc + *oneSquare*.yy - *oneSquare*.aa - *oneSquare*.bb  
 *oneSquare*.n8 = -*oneSquare*.mm + *oneSquare*.aa + *oneSquare*.bb  
 *oneSquare*.n9 = *oneSquare*.dd + *oneSquare*.mm + *oneSquare*.yy - *oneSquare*.aa - *oneSquare*.bb  
 *oneSquare*.n10 = -*oneSquare*.yy + *oneSquare*.aa + *oneSquare*.bb  
 square = SquareCollection()  
 myarray = square.toArray(*oneSquare*)  
   
 SquareCollections = numpy.concatenate((*SquareCollections*, [myarray] ), axis=0)  
 *return SquareCollections*# unit testing routine  
*def* test\_squares(*oneDate*):  
 #initialize square  
 myDate: Square = Square()  
 # intialize the data set array  
 data\_store: numpy.ndarray = numpy.ndarray((0, 21), dtype=int)  
 myDate.dd = *oneDate*.day  
 myDate.mm = *oneDate*.month  
 # trunc is to avoid decimals  
 myDate.cc = numpy.trunc(*oneDate*.year / 100)  
 myDate.yy = *oneDate*.year % 100  
 data\_store = find\_squares(myDate,data\_store)  
 *for* sq *in* data\_store:  
 #17th location is the magic square found.  
 *if* sq[16] == *True*:  
 print(sq)  
 print("Unit test passed!")  
  
*def* daterange(*start\_date*, *end\_date*):  
 *for* n *in* range(int ((*end\_date* - *start\_date*).days)):  
 *yield start\_date* + timedelta(n)   
  
#Finding possible squares with various combinations  
*def* find\_squares\_dates(*start\_date*, *end\_date*):  
 #intialize the data set array  
 data\_store:numpy.ndarray = numpy.ndarray((0,21),dtype=int)  
  
 *for* each\_date *in* daterange(*start\_date*, *end\_date*):  
  
 myDate:Square =Square()  
 myDate.dd = each\_date.day  
 myDate.mm = each\_date.month  
 #trunc is to avoid decimals  
 myDate.cc = numpy.trunc(each\_date.year / 100)  
 myDate.yy = each\_date.year % 100  
  
 data\_store = find\_squares(myDate, data\_store)  
  
 *return* data\_store  
# get random number  
*def* get\_random\_number(*high*):  
 *return* numpy.random.randint(0,*high*)  
  
# unit test the data load for a date  
test\_date = date(2005, 10, 17)  
test\_squares( test\_date )  
  
# for loading data Let us take first week of 2019  
start\_date = date(2019, 1, 1)  
end\_date = date(2019, 1, 7)  
  
# load magic square data for weeks  
dataset = find\_squares\_dates(start\_date, end\_date)  
  
# range of the input columns in the dataset  
xColumns = numpy.r\_[0:5, 8:9]  
  
# range of the output columns in the dataset  
# let us only evaluate magic or special for testing pupose.  
yColumns = numpy.r\_[16:18]  
# otherwise un comment the following  
# yColumns = numpy.r\_[5:8, 9:21]  
  
# split into input and output variables  
X\_input = dataset[:, xColumns]  
Y\_output = dataset[:, yColumns]  
  
  
# seed is initialized to get same results  
seed = 5  
numpy.random.seed(seed)  
  
# split the data into training (67%) and testing (33%)  
(X\_train, X\_test, Y\_train, Y\_test) = train\_test\_split(X\_input, Y\_output, test\_size=0.33, random\_state=seed)  
  
# create the model  
model = Sequential()  
# add the first hidden layer of input columns with 8 nodes, also called a Neuron or Perceptron  
model.add(Dense(8, input\_dim=xColumns.size, activation='relu', kernel\_initializer='uniform'))  
# add the second hidden layer with 6 nodes  
model.add(Dense(6, activation='relu', kernel\_initializer='uniform'))  
# finally add output columns  
model.add(Dense(yColumns.size, activation='sigmoid', kernel\_initializer='uniform'))  
  
# compile the model  
# loss function : maximum likelihood, error between 2 probability distributions measured using cross-entropy  
# optimizer: The Adam optimization algorithm, an extension to stochastic gradient descent to increase the learning rate

model.compile(loss='binary\_crossentropy', optimizer='adam', metrics=['accuracy'])  
  
# fit the model  
# training occurs over epochs(One pass through all rows in training dataset) and each epoch is split into batches  
# verbose is to display the training sessions in console  
model.fit(X\_train, Y\_train, validation\_data=(X\_test, Y\_test), epochs=10, batch\_size=5, verbose=1)  
  
# finally evaluate the model  
scores = model.evaluate(X\_test, Y\_test)  
print("Accuracy: %.2f%%" % (scores[1]\*100))  
  
# initalize to randomly generate 100 dates  
predict\_date\_variables: numpy.ndarray = numpy.ndarray((0, 6), dtype=int)  
# randomly generate 100 dates  
*for* myrandom *in* range(99):  
 myRandArray = numpy.array([1+get\_random\_number(27), 1+get\_random\_number(11), 18+get\_random\_number(2),  
 1+get\_random\_number(98), 1+get\_random\_number(98), 1+get\_random\_number(98)],dtype=int)  
 predict\_date\_variables = numpy.concatenate((predict\_date\_variables, [myRandArray]), axis=0)  
# guess predictions for given days at a time  
predictions = model.predict(predict\_date\_variables)  
pointer = 0  
*for* each\_day *in* predict\_date\_variables:  
 print("date: %d / %d / %d%d " %(each\_day[0], each\_day[1], each\_day[2], each\_day[3]))  
 print("Magic Availability: %.2f%% Super Magic Availability: %.2f%%"  
 %(predictions[pointer][0]\*100, predictions[pointer][0]\*100) )

The same principle can be extended to speedup:

1. Chat bots to find suitable answers from given questions’ phrases
2. Prescription and medication based on patients’ demographics, vitals and chief complaints
3. Preventative maintenance schedule alert based on the sounds or materials used
4. Prediction of agriculture yields, weather reports, stock markets, prices and so on…

💬 Let me know your thoughts in the comments! Additionally, for insights into various technical, business, and cultural topics, feel free to visit or if you have any questions or wish to discuss further, you can reach out to me via:

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Let’s spark conversations about how mathematics and AI continue to shape our world.

Let’s celebrate the brilliance of Ramanujan and the joy of mathematics together!

**Happy Ramanujan Day! – S. Lakshmanaraj**