KOÇ ÜNİVERSİTESİ

Lab10

COMP 125 Programming with Python

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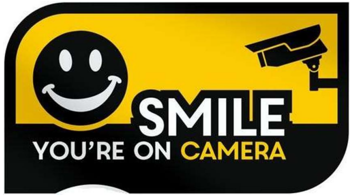

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Matrix Operations

A matrix is a collection of n-by-m elements in n-rows and m-columns with a_{ij} denoting the element of the matrix at the i-th row and j-th column . Matrices can be stored as list-of-lists in python

$$A=\begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1m} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2m} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3m} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nm} \end{bmatrix}$$

$$\begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \end{bmatrix}$$

```python
A=[ [1, 2, 3], [3, 2, 1]]
```

Matrix Sum

Summation of two matrices A and B with identical dimensions

(same number of rows and columns) is performed as follows:

$$
\begin{bmatrix}
a_{11} & a_{12} & \dots & a_{1m} \\
a_{21} & a_{22} & \dots & a_{2m} \\
\dots & \dots. & \dots. & \dots \\
a_{n1} & a_{n2} & \dots & a_{nm}
\end{bmatrix}
+
\begin{bmatrix}
b_{11} & b_{12} & \dots & b_{1m} \\
b_{21} & b_{22} & \dots & b_{2m} \\
\dots & \dots & \dots & \dots \\
b_{n1} & b_{n2} & \dots & b_{nm}
\end{bmatrix}
=
\begin{bmatrix}
a_{11}+b_{11} & a_{12}+b_{12} & \dots & a_{1m}+b_{1m} \\
a_{21}+b_{21} & a_{22}+b_{22} & \dots & a_{2m}+b_{2m} \\
\dots & \dots & \dots & \dots \\
a_{n1}+b_{n1} & a_{n2}+b_{n2} & \dots & a_{nm}+b_{nm}
\end{bmatrix}
$$

Matrix functions

Download the file Lab10a.py

The file contains three matrix functions that are already implemented

```
import random

def matrix_generate(n,m):
    """Receives the number of rows n and number of columns m
    and generates a matrix of size n-by-m with entries choosen as
    random values in the range (0,10).
    The return matrix is stored as a list-of-lists"""

    a = [[ random.randint(0,10) for i in range(m)] for j in range(n)]

    return a

def matrix_check(a):
    """Given a matrix a check if each row has the same elements.
    If corrent return True, else return False."""

    n=len(a)
    m=len(a[0])
    for i in range(1,n):
        if len(a[i]) != m:
            return False
    return True

def matrix_display(a):
    """Display the entries of a matrix as shown in the slides
    This function has no return. It simply prints a
    formatted view of the matrix. """

    n=len(a)
    m=len(a[0])
    out=""
    for i in range(n):
        out += "["
        for j in range(m):
            out += f"{a[i][j]:4}"
        out +=" ]\n"
    print(out)
```

Matrix functions

Your task is to implement

```
def matrix_sum(a,b):
    """ Given two matrices a and b, check the size
    of the matrices.
    If the sizes match, calculate the sum of the matrices
    and return the resulting matrix.
    """

    return
```

It should work as follows:

```
In [2]: #Let's create two 2-by-3 matrices
   ...: n = 2
   ...: m = 3
   ...: A = matrix_generate(n,m)
   ...: B = matrix_generate(n,m)

In [3]: #Display the matrices
   ...: print("Matrix A")
   ...: matrix_display(A)
   ...: print("Matrix B")
   ...: matrix_display(B)
Matrix A
[   4   7   0 ]
[   8   3   9 ]

Matrix B
[   1   1  10 ]
[   4   9   1 ]
```

```
In [4]: #Check the size of the matrices
   ...: print("Is A a proper matrix?")
   ...: print(matrix_check(A))
   ...: print("Is B a proper matrix?")
   ...: print(matrix_check(B))
Is A a proper matrix?
True
Is B a proper matrix?
True

In [5]: #Display the sum of the matrices
   ...: print("Matrix C = A+B")
   ...: C = matrix_sum(A,B)
   ...: matrix_display(C)
Matrix C = A+B
[   5   8  10 ]
[  12  12  10 ]
```

Sparse Matrix

- A matrix is called a Sparse Matrix if majority of its elements are zero.
- Storing a sparse matrix as list-of-lists is not very efficient.
- Alternatively, one can store only the non-zero elements, by using a dictionary in Python.
- **keys**: indices (i,j) of nonzero elements
- **values**: non-zero values to be stored.
- In order to keep the size of the matrix, add a special key **'size'**, which contains a tuple **(n,m)** containing the matrix dimensions.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Sparse Matrix functions

Download the file Lab10b.py

The file contains two functions that are already implemented.

It also imports Lab10a.py as a module. So this file has to be in the same folder.

```
import Lab10a
import random
def generate_random_sparse_matrix(n, m, spar=0.9):
    """
    This function generates a random matrix as a
    list of lists with a given sparsity.
    """

    a = [[ 0 for i in range(m)] for j in range(n)]

    #How many elements should be nonzero
    nr = int((1.-spar)*n*m)
    pos = random.sample(range(n*m), nr)
    for ind in pos:
        n_ind = int(ind/n)
        m_ind = ind-n_ind*m
        a[n_ind][m_ind]=1
    return a

def dense_to_sparse(A):
    """
    This function converts a list-of-lists type matrix
    to the sparse representation stored in a dictionary
    """
    sp = {}

    n = len(A)
    m = len(A[0])

    for i in range(n):
        for j in range(m):
            if A[i][j]:
                sp[(i,j)]=A[i][j]
    sp['size']= n,m
    return sp
```

Sparse Matrix functions

Your task is to implement

```python
def matrix_add_sparse(A, B):
    """
    Given two dictionaries, which contain the sparse matrix
    representations of matrices A and B, this function calculates the
    matrix sum and returns a new dictionary.

    """
```

Hint: You should not write a nested for-loop structure to iterate over the full size matrix. This would defeat the purpose !!!

Sparse Matrix functions

It should work as follows

```
In [31]: #Let's generate a sparse matrix of size 4-by-4
    ...: #Only half the elements are non-zero
    ...: A = (generate_random_sparse_matrix(4,4,.5))
    ...: matrix_display(A)
[   1   1   0   0 ]
[   0   1   0   0 ]
[   1   0   1   0 ]
[   0   1   1   1 ]


In [32]: #Convert list-of-lists to sparse representation
    ...: A_sp = dense_to_sparse(A)
    ...: print(A_sp)
{(0, 0): 1, (0, 1): 1, (1, 1): 1, (2, 0): 1, (2, 2): 1, (3, 1): 1, (3, 2): 1, (3, 3): 1, 'size': (4, 4)}

In [33]: #Create a second matrix
    ...: B = (generate_random_sparse_matrix(4,4,.5))
    ...: matrix_display(B)
    ...:
    ...: #Convert list-of-lists to sparse representation
    ...: B_sp = dense_to_sparse(B)
    ...: print(B_sp)
[   1   0   0   0 ]
[   0   0   1   1 ]
[   1   1   1   0 ]
[   0   0   1   1 ]

{(0, 0): 1, (1, 2): 1, (1, 3): 1, (2, 0): 1, (2, 1): 1, (2, 2): 1, (3, 2): 1, (3, 3): 1, 'size': (4, 4)}

In [34]: #Here is the sum of matrices A+B
    ...: print(matrix_add_sparse(A_sp,B_sp))
{(0, 0): 2, (0, 1): 1, (1, 1): 1, (2, 0): 2, (2, 2): 2, (3, 1): 1, (3, 2): 2, (3, 3): 2, 'size': (4, 4), (1, 2): 1,
(1, 3): 1, (2, 1): 1}
```