Laboratorio 2 – Sistemi Lineari


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Esercizio 1

L'obbiettivo del primo esercizio era calcolare la norma ∞ delle seguenti matrici:

- A = $\begin{pmatrix} 3 & 1 & -1 & 0 \\ 0 & 7 & -3 & 0 \\ 0 & -3 & 9 & -2 \\ 0 & 0 & 4 & -10 \end{pmatrix}$, A = $\begin{pmatrix} 2 & 4 & -2 & 0 \\ 1 & 3 & 0 & 1 \\ 3 & -1 & 1 & 2 \\ 0 & -1 & 2 & 1 \end{pmatrix}$
- A = P, dove P è la matrice di Pascal nxn definita nel seguente modo:

$$(P)_{ij} = \frac{(i+j-2)!}{(i-1)!(j-1)!} \quad \text{i,j = 1,…n} \quad \text{con n = 10}$$

- A = T, dove T è la matrice tridiagonale nxn (n= numero di matricola) definita dalle seguenti formule:

$$(T)_{i,j} = 2 \;\; se \;\; i = j;$$
$$(T)_{i,j} = -1 \;\; se \; |i-j| = 1$$
$$altrimenti \; (T)_{i,j} = 0$$

Le norme matriciali hanno diverse proprietà:

- $||A|| \geq 0$ e $||A|| = 0 \Leftrightarrow A = 0$
- $||aA|| = |a| * ||A|| \;\; \forall A, \forall a \in R$
- $||A+B|| \leq ||A|| + ||B|| \; \forall A,B \in R^{mxn}$
- $||A*B|| \leq ||A|| * ||B|| \; \forall A,B \in R^{nxn}$

La norma infinito si calcola:

$$||A||_\infty := MAX_{i=1,\dots,n} \sum_{j=1}^{n} |a_{ij}|$$

Norma Infinto delle diverse matrici proposte:

```
davide@davide:~/Uni/ALAN/2-Sistemi$ ./es1
Scegliere di quali matrici calcolare la norma infinito:
0-Termina
1-Matrici inserite dall'utente
2-Matrice di Pascal 10x10
3-Matrice Tridiagonale nxn
1


-------------------------------------------
Enter no. of rows: 4
Enter no. of columns: 4
Enter the values in the matrix:
Enter A[1][1]: 3
Enter A[1][2]: 1
Enter A[1][3]: -1
Enter A[1][4]: 0
Enter A[2][1]: 0
Enter A[2][2]: 7
Enter A[2][3]: -3
Enter A[2][4]: 0
Enter A[3][1]: 0
Enter A[3][2]: -3
Enter A[3][3]: 9
Enter A[3][4]: -2
Enter A[4][1]: 0
Enter A[4][2]: 0
Enter A[4][3]: 4
Enter A[4][4]: -110
La norma infinito della matice A e': 114
```

```
Scegliere di quali matrici calcolare la norma infinito:
0-Termina
1-Matrici inserite dall'utente
2-Matrice di Pascal 10x10
3-Matrice Tridiagonale nxn
1


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Enter no. of rows: 4
Enter no. of columns: 4
Enter the values in the matrix:
Enter A[1][1]: 2
Enter A[1][2]: 4
Enter A[1][3]: -2
Enter A[1][4]: 0
Enter A[2][1]: 1
Enter A[2][2]: 3
Enter A[2][3]: 0
Enter A[2][4]: 1
Enter A[3][1]: 3
Enter A[3][2]: -1
Enter A[3][3]: 1
Enter A[3][4]: 2
Enter A[4][1]: 0
Enter A[4][2]: -1
Enter A[4][3]: 2
Enter A[4][4]: 1
La norma infinito della matice A e': 8
```

```
Scegliere di quali matrici calcolare la norma infinito:
0-Termina
1-Matrici inserite dall'utente
2-Matrice di Pascal 10x10
3-Matrice Tridiagonale nxn
2



--------------------------------------------
La norma infinito della matice P e': 92378
1       1       1       1       1       1       1       1       1       1
1       2       3       4       5       6       7       8       9       10
1       3       6       10      15      21      28      36      45      55
1       4       10      20      35      56      84      120     165     220
1       5       15      35      70      126     210     330     495     715
1       6       21      56      126     252     462     792     1287    2002
1       7       28      84      210     462     924     1716    3003    5005
1       8       36      120     330     792     1716    3432    6435    11440
1       9       45      165     495     1287    3003    6435    12870   24310
1       10      55      220     715     2002    5005    11440   24310   48620
```

```
--------------------------------------------
La norma infinito della matice T e': 4
2 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```

Esercizio 2

I calcoli vengono svolti in doppia precisione, in C++ linguaggio utilizzato per il programma, abbiamo utilizzato come variabili per gli elementi da calcolare i double.
Come da testo costruiamo le matrici definite al punto 1 con le appropriate funzioni che utilizzano la memoria dinamica.

```
Matrice A1:
3       1       -1      0
0       7       -3      0
0       -3      9       -2
0       0       4       -10

Matrice A2:
2       4       -2      0
1       3       0       1
3       -1      1       2
0       -1      2       1

Matrice Pascal:
1       1       1       1       1       1       1       1       1       1
1       2       3       4       5       6       7       8       9       10
1       3       6       10      15      21      28      36      45      55
1       4       10      20      35      56      84      120     165     220
1       5       15      35      70      126     210     330     495     715
1       6       21      56      126     252     462     792     1287    2002
1       7       28      84      210     462     924     1716    3003    5005
1       8       36      120     330     792     1716    3432    6435    11440
1       9       45      165     495     1287    3003    6435    12870   24310
1       10      55      220     715     2002    5005    11440   24310   48620
```

In matematica, in particolare nella teoria delle matrici e nella combinatoria, la matrice Pascal è una matrice infinita contenente i coefficienti binomiali come suoi elementi. Ci sono tre modi per ottenere questo risultato: come matrice triangolare superiore, matrice triangolare inferiore (matrici triangolari) o matrice simmetrica.
Da <https://en.wikipedia.org/wiki/Pascal_matrix>

Un sistema di equazioni lineari:

$$\begin{cases} a_{1,1}x_1 + a_{1,2}x_2 + \cdots + a_{1,n}x_n & = & b_1 \\ a_{2,1}x_1 + a_{2,2}x_2 + \cdots + a_{2,n}x_n & = & b_2 \\ & \vdots & \\ a_{m,1}x_1 + a_{m,2}x_2 + \cdots + a_{m,n}x_n & = & b_m \end{cases}$$

La descrizione per utilizzare al meglio l'algoritmo è tramite una matrice che è proprio quello che abbiamo utilizzato per questo laboratorio

$$\begin{pmatrix} a_{1,1} & \cdots & a_{1,n} & b_1 \\ \vdots & \ddots & \vdots & \vdots \\ a_{m,1} & \cdots & a_{m,n} & b_m \end{pmatrix}$$

A questo punto abbiamo calcolato il prodotto dato dalla matrice b = A · x¯ con il risultato abbiamo poi ricavato i **termini noti**

```
Calcolo termine noto matrice A1 = 3 4 4 -6

Calcolo termine noto matrice A2 = 4 5 5 2

Calcolo termine noto matrice Pascal = 10 55 220 715 2002 5005 11440 24310 48620 92378

Calcolo termine noto matrice Tridiagonale = 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
```

```
- Soluzioni Gauss Matrice A1 -
x1 = 1  x2 = 1  x3 = 1  x4 = 1

- Soluzioni Gauss Matrice A2 -
x1 = 1  x2 = 1  x3 = 1  x4 = 1

- Soluzioni Gauss Matrice B -
x1 = 1  x2 = 1  x3 = 1  x4 = 1  x5 = 1  x6 = 1  x7 = 1  x8 = 1  x9 = 1  x10 = 1

- Soluzioni Gauss Matrice C -
x1 = 1  x2 = 1  x3 = 1  x4 = 1  x5 = 1  x6 = 1  x7 = 0.999999   x8 = 0.999999  x9 = 0.999999    x10 = 0.999999  x11 = 0.999999  x12 = 0.999999  x13 = 0.999999 x14 = 0.999999   x15 = 0.999999  x16 = 0.999999  x17
 = 0.999999  x18 = 0.999999 x19 = 0.999999   x20 = 0.999999  x21 = 0.999999  x22 = 0.999999  x23 = 0.999999 x24 = 0.999999   x25 = 0.999999  x26 = 0.999999  x27 = 0.999999  x28 = 0.999999 x29 = 0.999999   x30 =
0.999999  x31 = 0.999999  x32 = 0.999999  x33 = 0.999999 x34 = 0.999999   x35 = 0.999999  x36 = 0.999999  x37 = 0.999999  x38 = 0.999999 x39 = 0.999999   x40 = 0.999999  x41 = 0.999999  x42 = 0.999998  x43 = 0.9
99998 x44 = 0.999998   x45 = 0.999998  x46 = 0.999998  x47 = 0.999998  x48 = 0.999998 x49 = 0.999998   x50 = 0.999998  x51 = 0.999998  x52 = 0.999998  x53 = 0.999998 x54 = 0.999999   x55 = 0.999999  x56 = 0.9999
99  x57 = 0.999999  x58 = 0.999999 x59 = 1  x60 = 1 x61 = 1 x62 = 1 x63 = 1 x64 = 1 x65 = 1 x66 = 1 x67 = 1 x68 = 1x69 = 1  x70 = 1 x71 = 1
davide@davide:~/Uni/ALAN/Errori_Sistemi/bin$
```

Scritto il programma di eliminazione Gaussiana per la risoluzione sistema Ax = b tramite Gauss in doppia precisione (double), tenendo presente l’implementazione di una procedura applicabile anche su matrici di dimensioni arbitrarie tramite le funzioni subordinate che manipolano i dati in maniera dinamica.

Il metodo di eliminazione di Gauss è usato in algebra lineare per determinare le soluzioni di un sistema di equazioni lineari, per calcolare il rango o l'inversa di una matrice.
L'algoritmo, attraverso l'applicazione di operazioni elementari dette mosse di Gauss, riduce la matrice in una forma detta a scalini.
La matrice così ridotta permette il calcolo del rango della matrice (che sarà pari al numero di scalini/pivot) nonché la risoluzione del sistema lineare ad essa associato.
Da <https://it.wikipedia.org/wiki/Metodo_di_eliminazione_di_Gauss>

Esercizio 3

Usando le stesse matrici dell’esercizio 2 andiamo a risolvere il sistema lineare A$\tilde{x}$ = b + δb
Dove δb è, per ogni termine noto b, il vettore di perturbazioni δb = $||b||_\infty$ * (-0.01, 0.01, -0.01, …, 0.01)^t

Le soluzioni ottenute, che corrispondono ai rispettivi sistemi lineari con termine noto b e b + δb, sono:

```
- Soluzioni Gauss Matrice A1 -
x1 = 1
x2 = 1
x3 = 1
x4 = 1


- Soluzioni Gauss Matrice A1 Perturbata -
x1 = 0.924901
x2 = 0.871027
x3 = 0.68573
x4 = 0.664959
```

```
- Soluzioni Gauss Matrice A2 -
x1 = 1
x2 = 1
x3 = 1
x4 = 1


- Soluzioni Gauss Matrice A2 Perturbata -
x1 = -4.725
x2 = 5.42
x3 = 4.14
x4 = -4.51
```

```
- Soluzioni Gauss Matrice Pascal -
x1 = 1
x2 = 1
x3 = 1
x4 = 1
x5 = 1
x6 = 1
x7 = 1
x8 = 1
x9 = 1
x10 = 1


- Soluzioni Gauss Matrice Pascal Perturbata -
x1 = -69410.6
x2 = 604330
x3 = -2.454e+006
x4 = 5.89586e+006
x5 = -9.1713e+006
x6 = 9.55778e+006
x7 = -6.66797e+006
x8 = 3.00253e+006
x9 = -792020
x10 = 93301.8
```

```
- Soluzioni Gauss Matrice Tridiagonale -
x1 = 1
x2 = 1
x3 = 1
x4 = 1
x5 = 1
x6 = 1
x7 = 0.999999
x8 = 0.999999
x9 = 0.999999
x10 = 0.999999
x11 = 0.999999
x12 = 0.999999
x13 = 0.999999
x14 = 0.999999
x15 = 0.999999
x16 = 0.999999
x17 = 0.999999
x18 = 0.999999
x19 = 0.999999
x20 = 0.999999
x21 = 0.999999
x22 = 0.999999
x23 = 0.999999
x24 = 0.999999
x25 = 0.999999
x26 = 0.999999
x27 = 0.999999
x28 = 0.999999
x29 = 0.999999
x30 = 0.999999
x31 = 0.999999
x32 = 0.999999
x33 = 0.999999
x34 = 0.999999
x35 = 0.999999
x36 = 0.999999
x37 = 0.999999
x38 = 0.999999
x39 = 0.999999
x40 = 0.999999
x41 = 0.999999
x42 = 0.999998
x43 = 0.999998
x44 = 0.999998
x45 = 0.999998
x46 = 0.999998
x47 = 0.999998
x48 = 0.999998
x49 = 0.999998
x50 = 0.999998
x51 = 0.999998
x52 = 0.999998
x53 = 0.999998
x54 = 0.999999
x55 = 0.999999
x56 = 0.999999
x57 = 0.999999
x58 = 0.999999
x59 = 1
x60 = 1
x61 = 1
x62 = 1
x63 = 1
x64 = 1
x65 = 1
x66 = 1
x67 = 1
x68 = 1
x69 = 1
x70 = 1
x71 = 1
```

```
- Soluzioni Gauss Matrice Tridiagonale Perturbata -
x1 = 0.510751
x2 = 0.0315027
x3 = 0.0372541
x4 = 0.0596722
x5 = 0.0645902
x6 = 0.0875082
x7 = 0.092093
x8 = 0.115249
x9 = 0.119655
x10 = 0.14295
x11 = 0.147245
x12 = 0.170631
x13 = 0.17485
x14 = 0.198301
x15 = 0.202465
x16 = 0.225963
x17 = 0.230085
x18 = 0.25362
x19 = 0.25771
x20 = 0.281273
x21 = 0.285337
x22 = 0.308924
x23 = 0.312966
x24 = 0.336574
x25 = 0.340598
x26 = 0.364221
x27 = 0.36823
x28 = 0.391868
x29 = 0.395864
x30 = 0.419514
x31 = 0.423498
x32 = 0.447159
x33 = 0.451133
x34 = 0.474804
x35 = 0.478768
x36 = 0.502447
x37 = 0.506404
x38 = 0.530091
x39 = 0.534041
x40 = 0.557734
x41 = 0.561677
x42 = 0.585377
x43 = 0.589314
x44 = 0.613019
x45 = 0.616951
x46 = 0.640661
x47 = 0.644589
x48 = 0.668303
x49 = 0.672226
x50 = 0.695945
x51 = 0.699864
x52 = 0.723587
x53 = 0.727502
x54 = 0.751229
x55 = 0.755141
x56 = 0.778871
x57 = 0.782779
x58 = 0.806512
x59 = 0.810418
x60 = 0.834154
x61 = 0.838057
x62 = 0.861795
x63 = 0.865695
x64 = 0.889436
x65 = 0.893334
x66 = 0.917077
x67 = 0.920972
x68 = 0.944718
x69 = 0.948611
x70 = 0.972359
x71 = 0.97625
```