Relazione secondo laboratorio

Calcolo numerico: Sistemi Lineari

Pezzano Enrico (S4825087)

PER COMPILARE ED ESEGUIRE IL CODICE DIGITARE A TERMINALE NELLA DIRECTORY LABO2
make

ESERCIZIO 1
Il primo esercizio è in preparazione dell'esercitazione stessa, nel senso che vengono inizializzate le quattro matrici che verranno utilizzate in seguito:

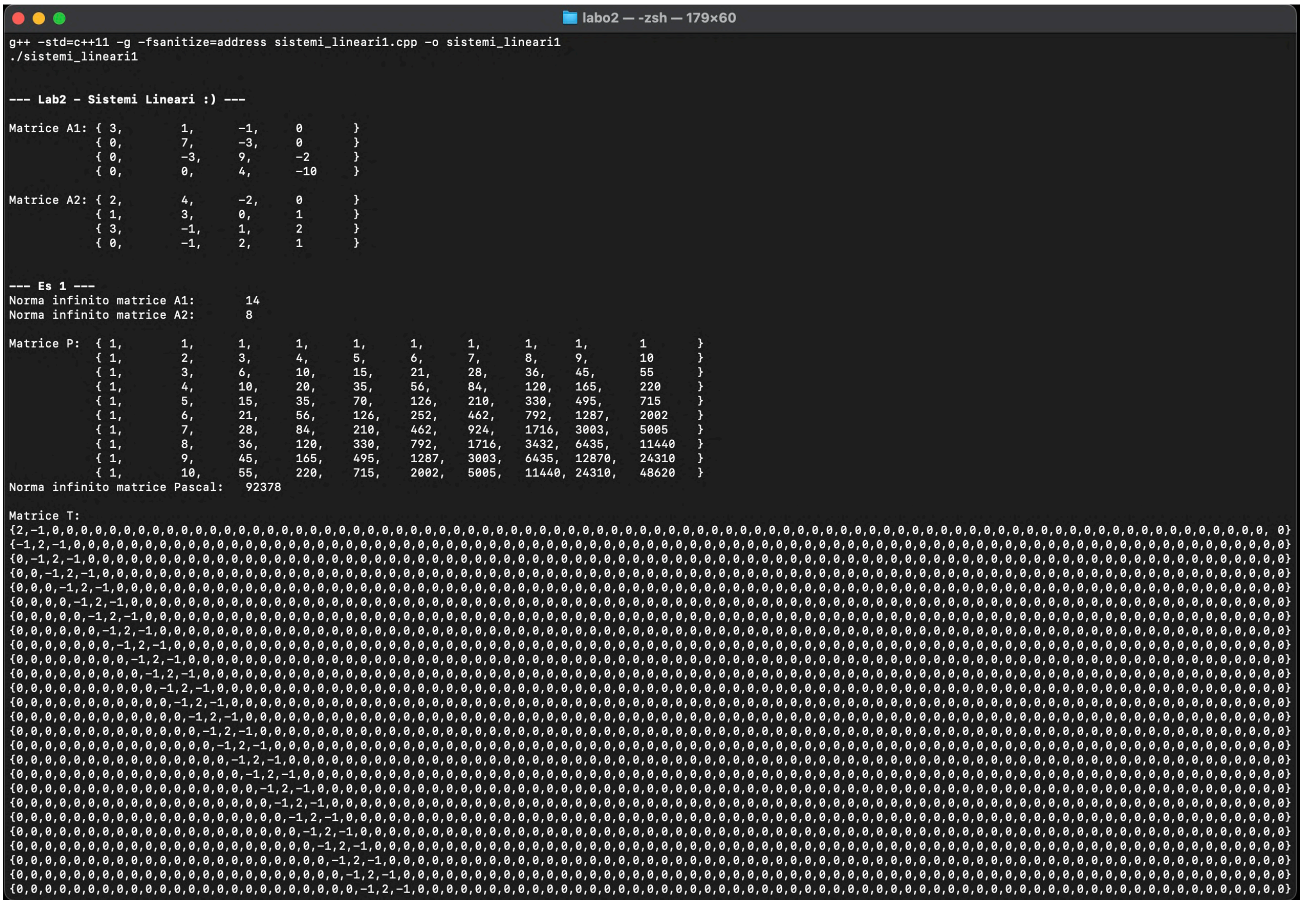
- A1: con numeri standard;
- A2: con numeri standard;
- P: generata tramite due cifre della matricola (8 2 7) e algoritmo per restituire matrice di Pascal;
- T: generata tramite algoritmo per restituire matrice tridiagonale.

Una volta che si hanno le matrici pronte, si calcola la loro norma infinito, ossia il massimo tra le somme dei moduli di tutti gli elementi delle righe delle matrici:

$$\|x\|_\infty = max_i\ |x_i|$$

Output programma:

OSSERVAZIONE OUTPUT:



```
labo2 — -zsh — 179×60
g++ -std=c++11 -g -fsanitize=address sistemi_lineari1.cpp -o sistemi_lineari1
./sistemi_lineari1


--- Lab2 - Sistemi Lineari :) ---

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       }


--- Es 1 ---
Norma infinito matrice A1:      14
Norma infinito matrice A2:      8

Matrice P:  { 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   }
Norma infinito matrice Pascal:   92378

Matrice T:
{2,-1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0}
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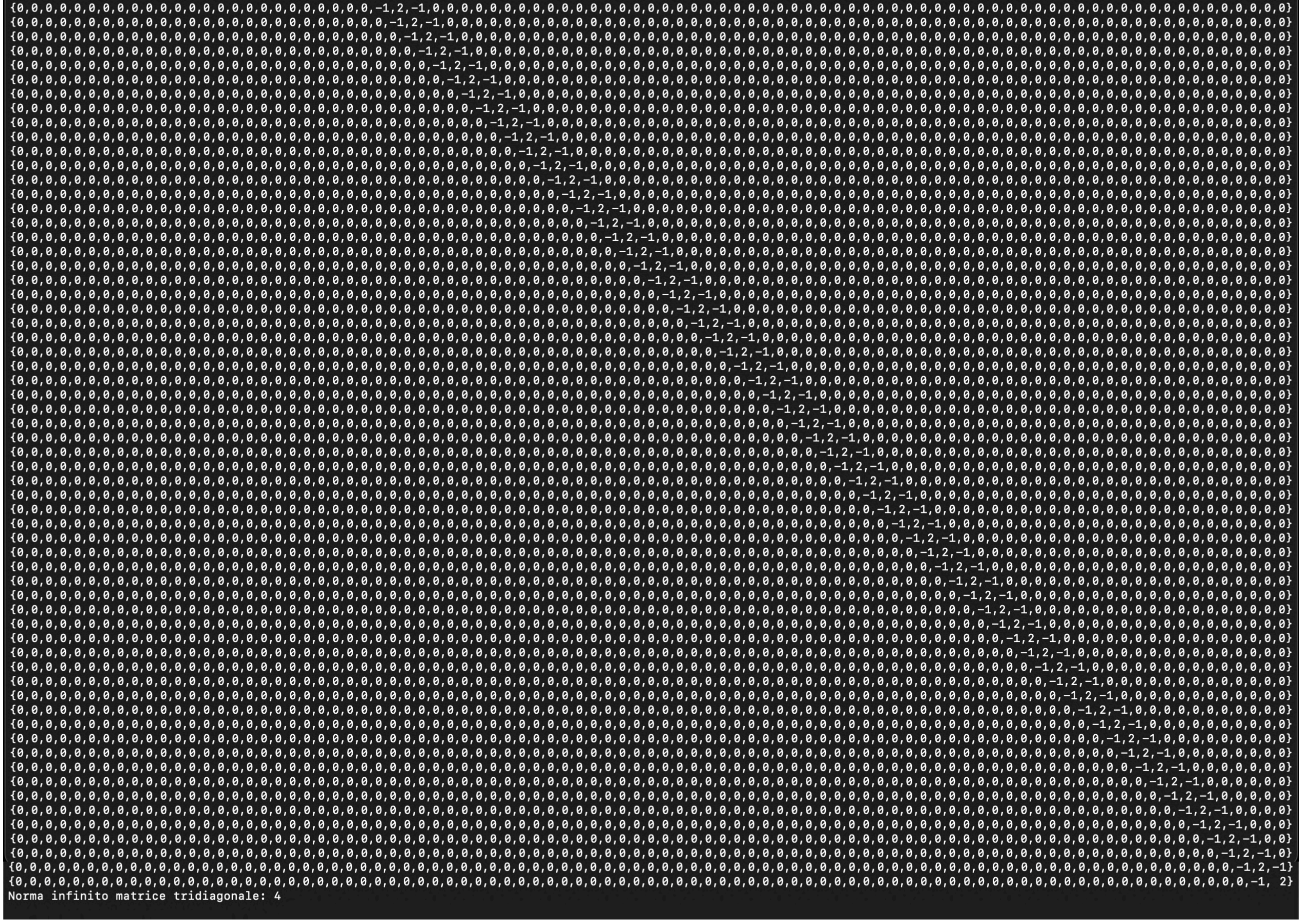
```



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{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0,0,0,0,0,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0,0,0,0,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0,0,0,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0,0,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1,0}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,2,-1}
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1, 2}
Norma infinito matrice tridiagonale: 4
```

- $||x||_{\infty}$ di A1 e 2 nella parte *a* risultano rispettivamente **14** e **8**;
- $||x||_{\infty}$ di P matrice di Pascal nella parte *b* con *n=10* risulta **92378**;
- $||x||_{\infty}$ di T matrice tridiagonale nella parte *c* con *n=88* risulta **4**.

ESERCIZIO 2

Nel secondo esercizio si osservano coefficienti di amplificazione dell'errore e stabilità delle matrici inizializzate nell'esercizio precedente

Nel dettaglio, si va ad analizzare il sistema:

$$Ax = b$$

tramite:

- *A* che verrà scambiata sequenzialmente dalle quattro matrici *A1*, *A2*, *P* e *T*;
- *x* vettore composto da soli 1;
- *b* vettore dei termini noti.

All'inizio si calcola *b* tramite formula (*B* = *Ax*, avendo *x* noto), poi *x* tramite algoritmo di *eliminazione gaussiana*.

Il vettore *x* calcolato prima dovrebbe essere uguale a quello di partenza, ossia composto solo da elementi uguali a 1. Ci si accorge empiricamente che risulta come aspettato.

Output programma:

```
g++ -std=c++11 -g -fsanitize=address sistemi_lineari2.cpp -o sistemi_lineari2
./sistemi_lineari2


--- Es 2 ---
Riutilizzando le stesse matrici dell'esercizio precedente...

***** Matrice A1 *****
Il vettore b di A1 e': {3, 4, 4, -6}

Il vettore x di A1 e': {1, 1, 1, 1}

***** Matrice A2 *****
Il vettore b di A2 e': {4, 5, 5, 2}

Il vettore x di A2 e': {1, 1, 1, 1}

***** Matrice P di Pascal *****
Il vettore b di P e': {10, 55, 220, 715, 2002, 5005, 11440, 24310, 48620, 92378}

Il vettore x di P e': {1, 1, 1, 1, 1, 1, 1, 1, 1, 1}

***** Matrice T triagonale *****
Il vettore b di T e': {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, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1}

Il vettore x di T e': {1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.9999
99, 0.999999, 1, 1, 1, 1, 1, 1, 1, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 0.999999, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}
```

ESERCIZIO 3
A questo punto si procede con la perturbazione del **vettore** *b*, risolvendo

$$Ax = b + \delta b$$

con il vettore *δb* composto da *-0,01* (per gli elementi di indice pari, partendo da 0 compreso) e *0,01* per gli elementi di indice dispari.
Successivamente si procede con la risoluzione dell'equazione tramite il terzo programma.

Output programma:

```
g++ -std=c++11 -g -fsanitize=address sistemi_lineari3.cpp -o sistemi_lineari3
./sistemi_lineari3


--- Es 3 ---
Riutilizzando le stesse matrici dell'esercizio precedente...

***** Matrice A1 *****
Vettore dei termini noti A1 perturbato:          {2.94, 4.06, 3.94, -5.94}
Somma dei vettori b di A1 con b di A1 perturbato: {5.94, 8.06, 7.94, -11.94}
Vettore soluzioni per A1:                         {1.97587, 2.0057, 1.99331, 1.99132}

***** Matrice A2 *****
Vettore dei termini noti A2 perturbato:          {3.95, 5.05, 4.95, 2.05}
Somma dei vettori b di A2 con b di A2 perturbato: {7.95, 10.05, 9.95, 4.05}
Vettore soluzioni per A2:                         {1.95, 2.015, 2.005, 2.055}

***** Matrice P *****
Vettore dei termini noti P perturbato:            {-913.78, 978.78, -703.78, 1638.78, 1078.22, 5928.78, 10516.2, 25233.8, 47696.2, 93301.8}
Somma dei vettori b di P con b di P perturbato:   {-903.78, 1033.78, -483.78, 2353.78, 3080.22, 10933.8, 21956.2, 49543.8, 96316.2, 185680}
Vettore soluzioni per P:                          {-944994, 7.56933e+06, -2.74286e+07, 5.86561e+07, -8.13369e+07, 7.57056e+07, -4.72384e+07, 1.90373e+07, -4.49327e+06, 472978}

***** Matrice T *****
Vettore dei termini noti T perturbato:
{0.99, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.
01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01
, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 1.01}

Somma dei vettori b di T con b di T perturbato:
{1.99, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.
01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01
, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 0.01, -0.01, 2.01}

Vettore soluzioni per T:
{1.99506, 2.00011, 1.99517, 2.00022, 1.99528, 2.00034, 1.99539, 2.00045, 1.9955, 2.00056, 1.99562, 2.00067, 1.99573, 2.00079, 1.99584, 2.0009, 1.99595, 2.00101, 1.99607, 2.00112, 1.99618, 2.00123, 1.99629
, 2.00135, 1.9964, 2.00146, 1.99652, 2.00157, 1.99663, 2.00168, 1.99674, 2.0018, 1.99685, 2.00191, 1.99697, 2.00202, 1.99708, 2.00213, 1.99719, 2.00225, 1.9973, 2.00236, 1.99741, 2.00247, 1.99752, 2.00258
, 1.99764, 2.00269, 1.99775, 2.00281, 1.99786, 2.00292, 1.99798, 2.00303, 1.99809, 2.00315, 1.9982, 2.00326, 1.99832, 2.00337, 1.99843, 2.00348, 1.99854, 2.0036, 1.99865, 2.00371, 1.99877, 2.00382, 1.9988
8, 2.00393, 1.99899, 2.00405, 1.9991, 2.00416, 1.99922, 2.00427, 1.99933, 2.00438, 1.99944, 2.0045, 1.99955, 2.00461, 1.99966, 2.00472, 1.99978, 2.00483, 1.99989, 2.00494}

Fine :-)
```

Si può osservare che a causa della perturbazione si ottengono risultati differenti per ognuna delle matrici.

I risultati con la perturbazione di *b* relativi alle matrici *A1*, *A2* e *T* (tridiagonale) sono poco divergenti dai calcoli dell'esercizio 2, nell'ordine delle unità, nel complesso le due soluzioni sono vicine tra loro.
Per la matrice di P di Pascal invece, si ottengono differenze significative dai calcoli "originali", che variano significativamente di valori da 1 a 48620, mentre le altre matrici hanno tutti valori molto vicini tra loro.
Si può vedere, infine, che confrontando con i risultati dell'esercizio 2, che le soluzioni differiscono significativamente solo per la matrice di Pascal.

In **conclusione**, le matrici *A1*, *A2* e *T* sono piuttosto **stabili** e **non amplificano** esageratamente l'errore. Al contrario, si può notare che la matrice P è estremamente **instabile** e **amplifica** enormemente l'errore, portando a soluzioni finali diverse.
Il problema è quindi ben condizionato per le matrici *A1*, *A2* e T*,* mentre è mal condizionato per quella di Pascal (*P*).