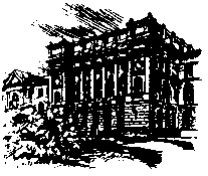
Санкт-Петербургский политехнический университет Петра Великого Институт компьютерных наук и технологий

Высшая школа программной инженерии

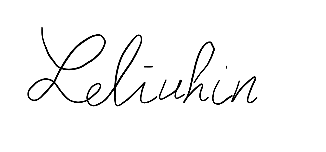


**Получение выходного сигнала с помощью КИХ-фильтра**

## Расчетное задание №2 по курсу

Цифровая обработка и передача многомерных сигналов

Вариант № 7



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Руководитель: Сараджишвили С.Э.

Санкт-Петербург 2019

# Задание

Есть импульсный отклик ЛИС-системы . Необходимо найти реакцию системы на входной сигнал двумя способами:

1) с помощью дискретной свертки: = \*\* ;

2) путем суммирования взвешенных и сдвинутых импульсных откликов;

# Подготовительный этап

Определим размер выходной матрицы y. Пусть h имеет размерность N 1 x N 2, a x – M 1 x M 2 . Тогда размерность матрицы y – L 1 x L 2 будет:

L 1 = N 1 + M 1 – 1 = 7 + 8 – 1 = 14

L 2 = N 2 + M 2 – 1 = 7 + 7 – 1 = 13

# Текст программы

Программы для вычисления реакции системы написаны на языке С++ 11, в среде разработки Qt Creator 5.9.2. Программа для визуализации данных написана с использованием среды MatLab R2016a.

## **1) Вычисление дискретной свертки**

#include <stdio.h>

#define H\_ROW 7

#define H\_COL 7

#define X\_ROW 8

#define X\_COL 7

#define Y\_ROW (H\_ROW + X\_ROW - 1)

#define Y\_COL (H\_COL + X\_COL - 1)

void PrintMatrix(FILE\* file, int\* matrix[], const char\* type)

{

int row, col;

if (type == "H")

{

row = H\_ROW;

col = H\_COL;

} // (type == "H")

else if (type == "X")

{

row = X\_ROW;

col = X\_COL;

} // (type == "X")

else

{

row = Y\_ROW;

col = Y\_COL;

} // (type != "X") && (type != "H")

fprintf(file, "======= Matrix %s(%d, %d)=======\n", type, row, col);

for (int i = 0; i < row; i++)

{

for (int j = 0; j < col; j++)

{

fprintf(file, "%d\t", matrix[i\*col + j]);

} // for (int j = 0; j < col; j++)

fprintf(file, "\n");

} // for (int i = 0; i < row; i++)

fprintf(file, "\n\n");

}

int main()

{

int h[H\_ROW][H\_COL] = { { 3, 3, 2, 2, 1, 1, 2 },

{ 1, 1, 4, 3, 3, 2, 0 },

{ 2, 2, 3, 4, 0, 5, 4 },

{ 2, 4, 3, 3, 2, 1, 0 },

{ 0, 4, 2, 0, 3, 6, 5 },

{ 0, 3, 2, 4, 0, 5, 7 },

{ 0, 3, 3, 0, 4, 4, 7 } };

int x[X\_ROW][X\_COL] = { { 0, 3, 3, 0, 5, 0, 0 },

{ 4, 2, 2, 4, 0, 4, 4 },

{ 5, 3, 2, 5, 3, 4, 7 },

{ 5, 4, 2, 0, 0, 4, 0 },

{ 0, 4, 1, 4, 0, 0, 8 },

{ 3, 3, 2, 0, 2, 4, 5 },

{ 0, 1, 3, 4, 0, 4, 6 },

{ 0, 4, 0, 5, 5, 0, 0 } };

int y[Y\_ROW][Y\_COL];

for (int i = 0; i < Y\_ROW; i++)

{

for (int j = 0; j < Y\_COL; j++)

{

y[i][j] = 0;

} // for(int j = 0; j < Y\_COL; j++)

} // for(int i = 0; i < Y\_ROW; i++)

for (int i = 0; i < Y\_ROW; i++)

{

for (int j = 0; j < Y\_COL; j++)

{

for (int k1 = 0; k1 < H\_ROW; k1++)

{

for (int k2 = 0; k2 < H\_COL; k2++)

{

if ((i - k1 >= 0) && (i - k1 < X\_ROW) && (j - k2 < X\_COL) && (j - k2 >= 0))

{

y[i][j] += h[k1][k2] \* x[i - k1][j - k2];

} // if((i-k1 >= 0)&&(i-k1 < X\_ROW)&&(j-k2 < X\_COL)&&(j-k2 >= 0))

} // for(int k2 = 0; k2 < H\_COL; k2++)

} // for(int k1 = 0; k1 < H\_ROW; k1++)

} // for(int j = 0; j < Y\_COL; j++)

} // for(int i = 0; i < Y\_ROW; i++)

FILE\* file = fopen("../method\_1.xls", "w");

if (file != NULL)

{

PrintMatrix(file, (int\*\*)h, "H");

PrintMatrix(file, (int\*\*)x, "X");

PrintMatrix(file, (int\*\*)y, "Y");

fclose(file);

} // if(file != NULL)

return 0;

}

## **2) Суммирование взвешенных и сдвинутых импульсных откликов**

#include <stdio.h>

#define H\_ROW 7

#define H\_COL 7

#define X\_ROW 8

#define X\_COL 7

#define Y\_ROW (H\_ROW + X\_ROW - 1)

#define Y\_COL (H\_COL + X\_COL - 1)

void PrintMatrix(FILE\* file, int\* matrix[], const char\* type)

{

int row, col;

if (type == "H")

{

row = H\_ROW;

col = H\_COL;

} // (type == "H")

else if (type == "X")

{

row = X\_ROW;

col = X\_COL;

} // (type == "X")

else

{

row = Y\_ROW;

col = Y\_COL;

} // (type != "X") && (type != "H")

fprintf(file, "======= Matrix %s(%d, %d)=======\n", type, row, col);

for (int i = 0; i < row; i++)

{

for (int j = 0; j < col; j++)

{

fprintf(file, "%d\t", matrix[i\*col + j]);

} // for (int j = 0; j < col; j++)

fprintf(file, "\n");

} // for (int i = 0; i < row; i++)

fprintf(file, "\n\n");

}

int main(void)

{

int h[H\_ROW][H\_COL] = { { 3, 3, 2, 2, 1, 1, 2 },

{ 1, 1, 4, 3, 3, 2, 0 },

{ 2, 2, 3, 4, 0, 5, 4 },

{ 2, 4, 3, 3, 2, 1, 0 },

{ 0, 4, 2, 0, 3, 6, 5 },

{ 0, 3, 2, 4, 0, 5, 7 },

{ 0, 3, 3, 0, 4, 4, 7 } };

int x[X\_ROW][X\_COL] = { { 0, 3, 3, 0, 5, 0, 0 },

{ 4, 2, 2, 4, 0, 4, 4 },

{ 5, 3, 2, 5, 3, 4, 7 },

{ 5, 4, 2, 0, 0, 4, 0 },

{ 0, 4, 1, 4, 0, 0, 8 },

{ 3, 3, 2, 0, 2, 4, 5 },

{ 0, 1, 3, 4, 0, 4, 6 },

{ 0, 4, 0, 5, 5, 0, 0 } };

int temp[Y\_ROW][Y\_COL];

int y[Y\_ROW][Y\_COL];

for (int i = 0; i < Y\_ROW; i++)

{

for (int j = 0; j < Y\_COL; j++)

{

y[i][j] = 0;

} // (int j = 0; j < Y\_COL; j++)

} // (int i = 0; i < Y\_ROW; i++)

FILE\* file = fopen("method\_2.xls", "w");

PrintMatrix(file, (int\*\*)h, "H");

PrintMatrix(file, (int\*\*)x, "X");

for (int k1 = 0; k1 < X\_ROW; k1++)

{

for (int k2 = 0; k2 < X\_COL; k2++)

{

for (int i = 0; i < Y\_ROW; i++)

{

for (int j = 0; j < Y\_COL; j++)

{

temp[i][j] = 0;

} // for (int j = 0; j < Y\_COL; j++)

} // (int i = 0; i < Y\_ROW; i++)

for (int m1 = 0; m1 < H\_ROW; m1++)

{

for (int m2 = 0; m2 < H\_COL; m2++)

{

temp[m1 + k1][m2 + k2] = h[m1][m2] \* x[k1][k2];

} // (int m2 = 0; m2 < H\_COL; m2++)

} // (int m1 = 0; m1 < H\_ROW; m1++)

char matr[12] = "";

sprintf(matr, "Temp\_%d\_%d", k1 + 1, k2 + 1);

PrintMatrix(file, (int\*\*)temp, matr);

for (int i = 0; i < Y\_ROW; i++)

{

for (int j = 0; j < Y\_COL; j++)

{

y[i][j] += temp[i][j];

} // (int j = 0; j < Y\_COL; j++)

} // (int i = 0; i < Y\_ROW; i++)

} // (int k2 = 0; k2 < X\_COL; k2++)

} // (int k1 = 0; k1 < X\_ROW; k1++)

PrintMatrix(file, (int\*\*)y, "Y");

fclose(file);

}

## **3) Построение 3D графиков реакции системы.**

function [] = plot\_out\_signals()

%% PLOT\_OUT\_SIGNALS

% Summary of this function goes here.

%

% \* Syntax

%

% [] = PLOT\_OUT\_SIGNALS()

%

% \* Input

%

% -- INPUTARGS -

%

% \* Output

%

% -- OUTPUTARGS -

%

% \* Examples:

%

% Provide sample usage code here

%

% \* See also:

%

% List related files here

%

% \* Author: Dmitrii Leliuhin

% \* Email: dleliuhin@mail.ru

% \* Date: 31/03/2019 15:18:11

% \* Version: 1.0 $

% \* Requirements: PCWIN64, MatLab R2016a

%

% \* Warning:

%

% # Warnings list.

%

% \* TODO:

%

% # TODO list.

%

%% Code

clc;

clear all;

close all;

y.rows = 14;

y.cols = 13;

file\_name\_1 = '../results/method\_1.xls';

file\_name\_2 = '../results/method\_2.xls';

Y\_1 = zeros(y.rows, y.cols);

Y\_2 = zeros(y.rows, y.cols);

xls\_range\_1 = 'A23:M36';

xls\_range\_2 = 'A975:M988';

Y\_1 = xlsread(file\_name\_1, xls\_range\_1);

Y\_2 = xlsread(file\_name\_2, xls\_range\_2);

figure;

title('Метод 1. Вычисление дискретной свертки.', 'FontSize', 18);

surf(Y\_1)

saveas(gcf, '../results/method\_1', 'jpg');

figure;

title('Метод 2. Суммирование взвешенных и сдвинутых импульсных откликов.', ...

'FontSize', 18);

surf(Y\_2)

saveas(gcf, '../results/method\_2', 'jpg');

figure;

surf(Y\_1);

view(2);

snapnow;

saveas(gcf, '../results/2D-view', 'jpg');

save('../results/workspace.mat');

close all;

end

# Результаты

## **1) Вычисление дискретной свертки**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 9 | 18 | 15 | 27 | 24 | 16 | 19 | 11 | 5 | 10 | 0 | 0 |
| 12 | 21 | 26 | 45 | 50 | 53 | 79 | 51 | 39 | 30 | 8 | 12 | 8 |
| 19 | 36 | 57 | 78 | 100 | 105 | 124 | 131 | 82 | 80 | 57 | 23 | 14 |
| 28 | 53 | 91 | 113 | 107 | 160 | 160 | 125 | 137 | 80 | 53 | 58 | 16 |
| 23 | 57 | 102 | 151 | 133 | 171 | 220 | 188 | 162 | 149 | 85 | 63 | 44 |
| 29 | 82 | 109 | 144 | 162 | 217 | 261 | 270 | 195 | 129 | 146 | 96 | 30 |
| 13 | 77 | 119 | 161 | 175 | 221 | 323 | 272 | 290 | 230 | 152 | 174 | 107 |
| 6 | 80 | 116 | 143 | 194 | 249 | 357 | 330 | 242 | 233 | 177 | 188 | 97 |
| 6 | 54 | 99 | 125 | 147 | 209 | 293 | 311 | 264 | 158 | 143 | 183 | 113 |
| 0 | 37 | 75 | 88 | 133 | 139 | 268 | 243 | 142 | 171 | 101 | 124 | 81 |
| 0 | 17 | 47 | 75 | 95 | 111 | 137 | 226 | 153 | 95 | 108 | 141 | 121 |
| 0 | 9 | 37 | 34 | 60 | 92 | 126 | 139 | 151 | 131 | 95 | 106 | 77 |
| 0 | 0 | 15 | 20 | 52 | 41 | 78 | 113 | 80 | 104 | 75 | 52 | 42 |
| 0 | 0 | 12 | 12 | 15 | 46 | 31 | 48 | 40 | 55 | 35 | 0 | 0 |

## **2) Суммирование взвешенных и сдвинутых импульсных откликов**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 9 | 9 | 6 | 6 | 3 | 3 | 6 | 0 | 0 | 0 | 0 | 0 |
| 0 | 3 | 3 | 12 | 9 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 6 | 6 | 9 | 12 | 0 | 15 | 12 | 0 | 0 | 0 | 0 | 0 |
| 0 | 6 | 12 | 9 | 9 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 12 | 6 | 0 | 9 | 18 | 15 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 9 | 6 | 12 | 0 | 15 | 21 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 9 | 9 | 0 | 12 | 12 | 21 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 9 | 9 | 6 | 6 | 3 | 3 |  | 6 | 0 | 0 | 0 | 0 |
| 0 | 0 | 3 | 3 | 12 | 9 | 9 | 6 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 6 | 9 | 12 | 0 | 15 |  | 12 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 12 | 9 | 9 | 6 | 3 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 12 | 6 | 0 | 9 | 18 |  | 15 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 9 | 6 | 12 | 0 | 15 |  | 21 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 9 | 9 | 0 | 12 | 12 |  | 21 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 15 | 15 | 10 | 10 | 5 | 5 | 10 | 0 | 0 |
| 0 | 0 | 0 | 0 | 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 10 | 10 | 15 | 20 | 0 | 25 | 20 | 0 | 0 |
| 0 | 0 | 0 | 0 | 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 15 | 30 | 25 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 15 | 10 | 20 | 0 | 25 | 35 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 15 | 15 | 0 | 20 | 20 | 35 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

=======================================================================================================

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 12 | 8 | 8 | 4 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 8 | 12 | 16 | 0 | 20 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 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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| 0 | 6 | 6 | 4 | 4 | 2 | 2 | 4 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | 2 | 8 | 6 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 4 | 4 | 6 | 8 | 0 | 10 | 8 | 0 | 0 | 0 | 0 | 0 |
| 0 | 4 | 8 | 6 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 8 | 4 | 0 | 6 | 12 | 10 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 4 | 8 | 0 | 10 | 14 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 6 | 0 | 8 | 8 | 14 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 4 | 8 | 6 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 8 | 4 | 0 | 6 | 12 | 10 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 6 | 4 | 8 | 0 | 10 | 14 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 6 | 6 | 0 | 8 | 8 | 14 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 |
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| 15 | 15 | 10 | 10 | 5 | 5 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 10 | 15 | 20 | 0 | 25 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 20 | 10 | 0 | 15 | 30 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 15 | 10 | 20 | 0 | 25 | 35 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 3 | 3 | 12 | 9 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 6 | 12 | 9 | 9 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 12 | 6 | 0 | 9 | 18 | 15 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 9 | 6 | 12 | 0 | 15 | 21 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 10 | 10 | 15 | 20 | 0 | 25 | 20 | 0 | 0 | 0 |
| 0 | 0 | 0 | 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 20 | 10 | 0 | 15 | 30 | 25 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 6 | 12 | 9 | 9 | 6 | 3 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 12 | 6 | 0 | 9 | 18 | 15 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 | 28 | 21 | 21 | 14 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 | 21 | 28 | 0 | 35 | 28 |
| 0 | 0 | 0 | 0 | 0 | 0 | 14 | 28 | 21 | 21 | 14 | 7 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 14 | 0 | 21 | 42 | 35 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 14 | 28 | 0 | 35 | 49 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 21 | 0 | 28 | 28 | 49 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 15 | 15 | 10 | 10 | 5 | 5 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 6 | 6 | 4 | 4 | 2 | 2 | 4 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 12 | 12 | 8 | 8 | 4 | 4 | 8 | 0 |
| 0 | 0 | 0 | 0 | 0 | 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 8 | 8 | 12 | 16 | 0 | 20 | 16 | 0 |
| 0 | 0 | 0 | 0 | 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 |
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| 0 | 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 8 | 8 | 12 | 16 | 0 | 20 | 16 | 0 | 0 | 0 | 0 | 0 |
| 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 32 | 24 | 24 | 16 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 24 | 32 | 0 | 40 | 32 |
| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 32 | 24 | 24 | 16 | 8 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 16 | 0 | 24 | 48 | 40 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 16 | 32 | 0 | 40 | 56 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 24 | 0 | 32 | 32 | 56 |
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| 9 | 9 | 6 | 6 | 3 | 3 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 | 12 | 9 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 6 | 9 | 12 | 0 | 15 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 3 | 3 | 12 | 9 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 8 | 8 | 12 | 16 | 0 | 20 | 16 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 20 | 15 | 15 | 10 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 15 | 20 | 0 | 25 | 20 |
| 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 15 | 15 | 10 | 5 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 15 | 30 | 25 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 3 | 3 | 2 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 4 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | 2 | 3 | 4 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | 4 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 3 | 3 | 12 | 9 | 9 | 6 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 6 | 9 | 12 | 0 | 15 | 12 | 0 | 0 | 0 | 0 |
| 0 | 0 | 6 | 12 | 9 | 9 | 6 | 3 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 12 | 6 | 0 | 9 | 18 | 15 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 9 | 6 | 12 | 0 | 15 | 21 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 9 | 9 | 0 | 12 | 12 | 21 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 4 | 4 | 16 | 12 | 12 | 8 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 8 | 8 | 12 | 16 | 0 | 20 | 16 | 0 | 0 | 0 |
| 0 | 0 | 0 | 8 | 16 | 12 | 12 | 8 | 4 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 8 | 16 | 0 | 20 | 28 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 16 | 16 | 28 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 24 | 18 | 18 | 12 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 18 | 24 | 0 | 30 | 24 |
| 0 | 0 | 0 | 0 | 0 | 0 | 12 | 24 | 18 | 18 | 12 | 6 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 12 | 0 | 18 | 36 | 30 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 | 0 | 24 | 24 | 42 |
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| 0 | 0 | 16 | 8 | 0 | 12 | 24 | 20 | 0 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 5 | 5 | 20 | 15 | 15 | 10 | 0 | 0 | 0 |
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| 0 | 0 | 0 | 0 | 10 | 20 | 15 | 15 | 10 | 5 | 0 | 0 | 0 |
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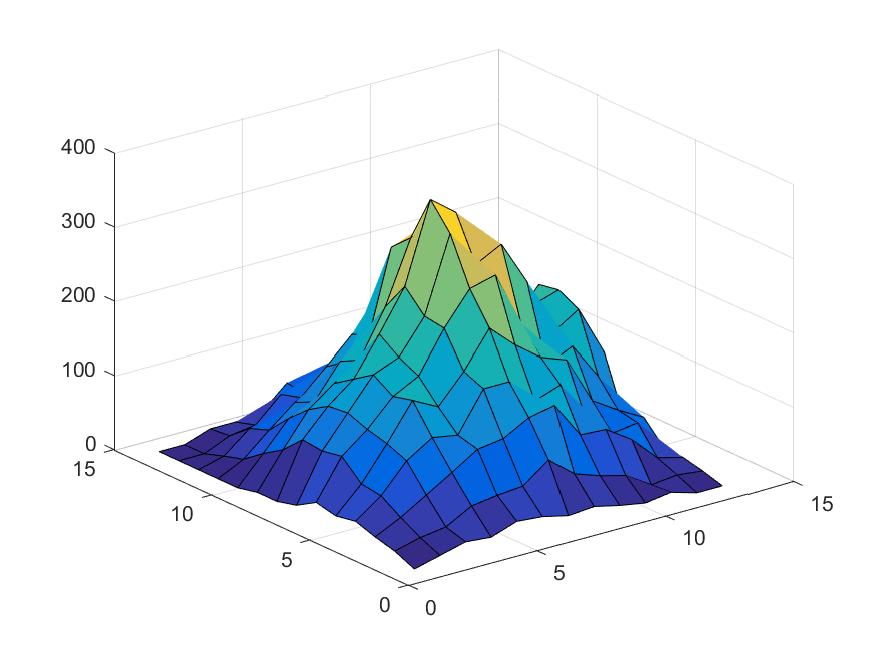
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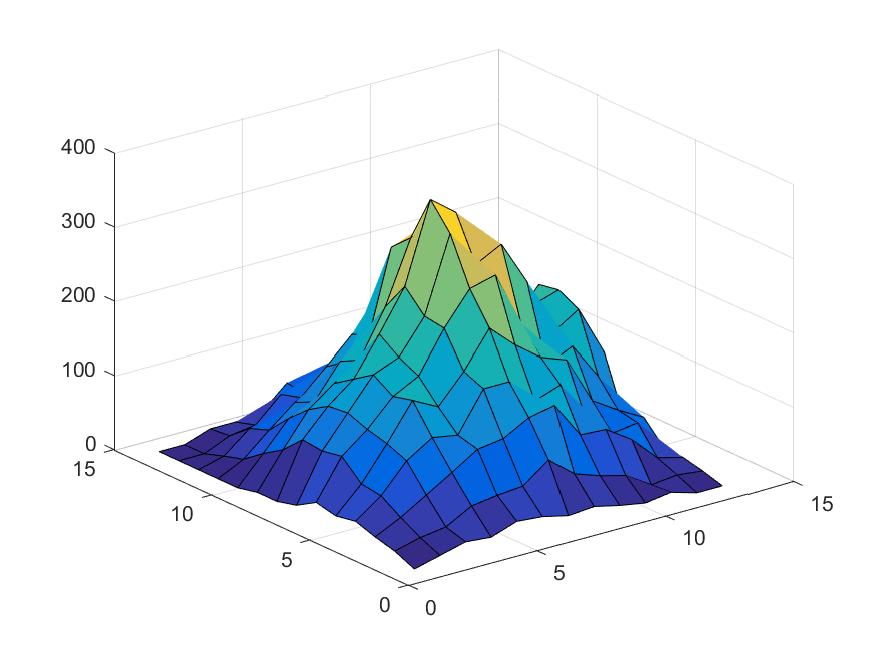
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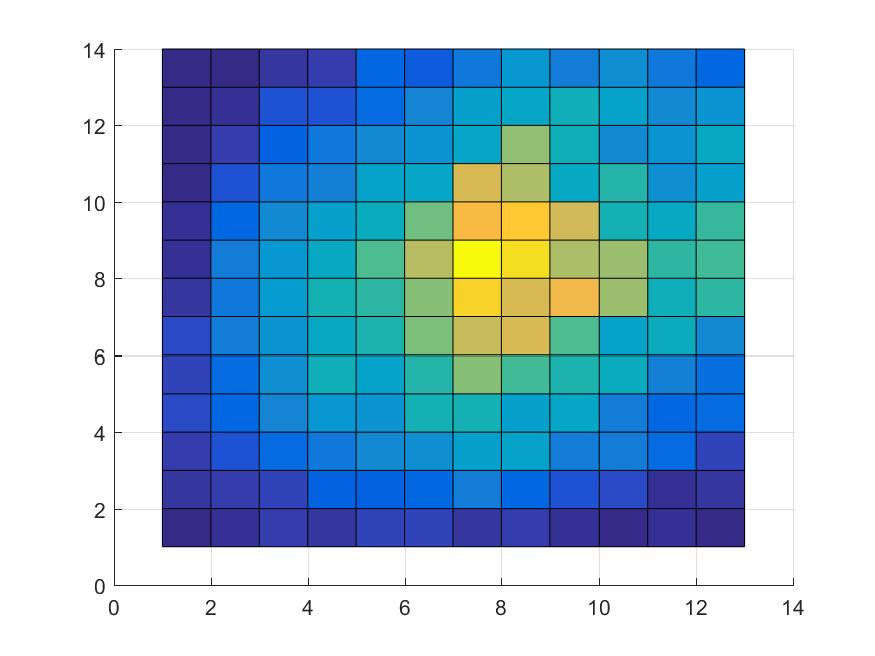
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| 19 | 36 | 57 | 78 | 100 | 105 | 124 | 131 | 82 | 80 | 57 | 23 | 14 |
| 28 | 53 | 91 | 113 | 107 | 160 | 160 | 125 | 137 | 80 | 53 | 58 | 16 |
| 23 | 57 | 102 | 151 | 133 | 171 | 220 | 188 | 162 | 149 | 85 | 63 | 44 |
| 29 | 82 | 109 | 144 | 162 | 217 | 261 | 270 | 195 | 129 | 146 | 96 | 30 |
| 13 | 77 | 119 | 161 | 175 | 221 | 323 | 272 | 290 | 230 | 152 | 174 | 107 |
| 6 | 80 | 116 | 143 | 194 | 249 | 357 | 330 | 242 | 233 | 177 | 188 | 97 |
| 6 | 54 | 99 | 125 | 147 | 209 | 293 | 311 | 264 | 158 | 143 | 183 | 113 |
| 0 | 37 | 75 | 88 | 133 | 139 | 268 | 243 | 142 | 171 | 101 | 124 | 81 |
| 0 | 17 | 47 | 75 | 95 | 111 | 137 | 226 | 153 | 95 | 108 | 141 | 121 |
| 0 | 9 | 37 | 34 | 60 | 92 | 126 | 139 | 151 | 131 | 95 | 106 | 77 |
| 0 | 0 | 15 | 20 | 52 | 41 | 78 | 113 | 80 | 104 | 75 | 52 | 42 |
| 0 | 0 | 12 | 12 | 15 | 46 | 31 | 48 | 40 | 55 | 35 | 0 | 0 |

## **Графическое представление выходного сигнала**

Графики построены в среде MatLab R2016a.







# Выводы

В ходе работы была найдена реакция импульсного отклика ЛИС-системы на входной сигнал двумя способами:

1) с помощью дискретной свертки: = \*\* ;

2) путем суммирования взвешенных и сдвинутых импульсных откликов;

Для этого были написаны программы для вычисления реакции системы двумя вышеперечисленными способами на языке C++. Результирующие массивы получились идентичными в обоих случаях, что подтверждает достоверность вычислений. Также были построены 3D графики для для визуализации многомерного выходного сигнала.