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Лабораторна робота №5

з дисципліни
«Алгоритми і структури даних»

Виконав

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номер у списку групи: 20

Перевірила:

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Постановка задачі :

1. Представити напрямлений граф з заданими параметрами так само, як у лабораторній роботі No3. Відміна: матриця A за варіантом формується за функцією:

A = mulmr((1.0 – n3*0.01 – n4*0.005 − 0.15)*T);

2. Створити програми для обходу в глибину та в ширину. Обхід починати з вершини, яка має вихідні дуги. При цьому у програмі:

— встановити зупинку у точці призначення номеру черговій вершині за допомогою повідомлення про натискання кнопки,

— виводити зображення графа у графічному вікні перед кожною зупинкою.

3. Під час обходу графа побудувати дерево обходу. Вивести побудоване дерево у графічному вікні.

Завдання варіанту № 20 :

Номер – 2220

Число вершин = 10 +2 = 12.

Розміщення вершин колом , бо n4 = 0;

Srand(2220)

Текст програми мовою С.

Файл *main.c* :

```c
#include <stdio.h>
#include <stdlib.h>
#include <windows.h>
#include <math.h>
#include "props.h"
#define vertices 12
#define IDC_BUTTON 1
#define IDC_BUTTON2 2

LRESULT CALLBACK WndProc(HWND, UINT, WPARAM, LPARAM);

char ProgName[] = "Lab 5";

struct coordinates {
```

```
    double nx[vertices];
    double ny[vertices];
    double loopX[vertices];
    double loopY[vertices];
};
void printMatrix(double **matrix, int n, int initialX, int initialY, HDC hdc)
{
  for (int i = 0, y = initialY + 30; i < n; i++, y += 15) {
    for (int j = 0, x = initialX; j < n; j++, x += 13) {
      wchar_t buffer[2];
      swprintf(buffer, 2, L"%lf", matrix[i][j]);
      TextOut(hdc, x, y, (LPCSTR) buffer, 1);
    }
    MoveToEx(hdc, initialX, y, NULL);
  }
}

void arrow(double fi, double px, double py, HDC hdc) {
  double lx, ly, rx, ry;
  lx = px + 15 * cos(fi + 0.3);
  rx = px + 15 * cos(fi - 0.3);
  ly = py + 15 * sin(fi + 0.3);
  ry = py + 15 * sin(fi - 0.3);
  MoveToEx(hdc, lx, ly, NULL);
  LineTo(hdc, px, py);
  LineTo(hdc, rx, ry);
}

void depictArch(int startX, int startY, int finalX, int finalY, int
archInterval, HDC hdc) {
  XFORM transformMatrix;
  XFORM initialMatrix;
  GetWorldTransform(hdc, &initialMatrix);

  double angle = atan2(finalY - startY, finalX - startX) - M_PI / 2.0;
  transformMatrix.eM11 = (FLOAT) cos(angle);
  transformMatrix.eM12 = (FLOAT) sin(angle);
  transformMatrix.eM21 = (FLOAT) (-sin(angle));
  transformMatrix.eM22 = (FLOAT) cos(angle);
  transformMatrix.eDx = (FLOAT) startX;
  transformMatrix.eDy = (FLOAT) startY;
  SetWorldTransform(hdc, &transformMatrix);

  const double archWidthRatio = 0.75;
  double archLength = sqrt((finalX - startX) * (finalX - startX) + (finalY -
startY) * (finalY - startY));
  double radiusOfVertex = 15.0;
  double semiMinorAxis = archWidthRatio * archLength;
  double semiMajorAxis = archLength / 2;

  double ellipseStartY = semiMajorAxis;

  double vertexAreaSquared = semiMajorAxis * semiMajorAxis * radiusOfVertex *
radiusOfVertex;
  double semiAxesSquared = semiMinorAxis * semiMinorAxis * semiMajorAxis *
semiMajorAxis;
  double distanceFromCenter = semiMinorAxis * semiMinorAxis * ellipseStartY *
ellipseStartY;
  double distanceFromVertex = semiMinorAxis * semiMinorAxis * radiusOfVertex
* radiusOfVertex;
  double semiMinorAxisPow = pow(semiMinorAxis, 4);

  double intersection = semiMajorAxis *
                        sqrt(vertexAreaSquared - semiAxesSquared +
```

```
distanceFromCenter - distanceFromVertex +
                              semiMinorAxisPow);
  double semiMinorAxisSquaredEllipseStartY = semiMinorAxis * semiMinorAxis *
ellipseStartY;
  double denominator = -semiMajorAxis * semiMajorAxis + semiMinorAxis *
semiMinorAxis;


  double contactYRightTop = (semiMinorAxisSquaredEllipseStartY -
intersection) / denominator;
  double contactXRightTop = sqrt(radiusOfVertex * radiusOfVertex -
contactYRightTop * contactYRightTop);
  double contactYBottom = archLength - contactYRightTop;
  double contactXLeftBottom = -contactXRightTop;

  if (archInterval <= vertices / 2) {
    Arc(hdc, -archWidthRatio * archLength, archLength, archWidthRatio *
archLength, 0, 0, 0, 0, archLength);
    double angleOfArrow = -atan2(archLength - contactYBottom,
contactXLeftBottom) + 0.3 / 3;
    arrow(angleOfArrow, contactXLeftBottom, contactYBottom, hdc);
  } else {
    Arc(hdc, -archWidthRatio * archLength, archLength, archWidthRatio *
archLength, 0, 0, archLength, 0, 0);
    double angleOfArrow = -atan2(archLength - contactYBottom, -
contactXLeftBottom) - 0.3 / 3;
    arrow(angleOfArrow, -contactXLeftBottom, contactYBottom, hdc);
  }

  SetWorldTransform(hdc, &initialMatrix);

}

void depictDirectedGraph(int centerX, int centerY, int radiusOfGraph, int
radiusOfVertex, int radiusOfLoop, double angle,
                         struct coordinates coordinates, double **matrix,
                         HPEN KPen, HPEN GPen, HDC hdc) {
  for (int i = 0; i < vertices; i++) {
    for (int j = 0; j < vertices; j++) {
      MoveToEx(hdc, coordinates.nx[i], coordinates.ny[i], NULL);
      if ((j >= i && matrix[i][j] == 1) || (j <= i && matrix[i][j] == 1 &&
matrix[j][i] == 0)) {
        if (i == j) {
          SelectObject(hdc, GPen);

          Ellipse(hdc, coordinates.loopX[i] - radiusOfLoop,
coordinates.loopY[i] - radiusOfLoop,
                  coordinates.loopX[i] + radiusOfLoop, coordinates.loopY[i] +
radiusOfLoop);


          double radiusOfContact = radiusOfGraph + radiusOfLoop / 2.;
          double triangleHeight = sqrt(3) * radiusOfVertex / 2.;
          double loopAngle = atan2(triangleHeight, radiusOfContact);
          double contactDistance = sqrt(radiusOfContact * radiusOfContact +
triangleHeight * triangleHeight);
          double angleToContactVertex = atan2(coordinates.ny[i] - centerY,
coordinates.nx[i] - centerX);

          double contactPointX = centerX + contactDistance *
cos(angleToContactVertex + loopAngle);
          double contactPointY = centerY + contactDistance *
sin(angleToContactVertex + loopAngle);
```

```
          double curvatureAngle = angleToContactVertex + 0.3 / 2.;
          arrow(curvatureAngle, contactPointX, contactPointY, hdc);
          SelectObject(hdc, KPen);
        } else {
          LineTo(hdc, coordinates.nx[j], coordinates.ny[j]);
          double line_angle = atan2(coordinates.ny[i] - coordinates.ny[j],
coordinates.nx[i] - coordinates.nx[j]);
          arrow(line_angle, coordinates.nx[j] + radiusOfVertex *
cos(line_angle),
                coordinates.ny[j] + radiusOfVertex * sin(line_angle), hdc);
        }
      } else if (j < i && matrix[i][j] == 1 && matrix[j][i] == 1) {
        depictArch(coordinates.nx[i], coordinates.ny[i], coordinates.nx[j],
coordinates.ny[j], fabs(i - j), hdc);
      }

    }
  }
}

int dfsIterationAmount = 0;
int bfsIterationAmount = 0;

int WINAPI WinMain(HINSTANCE hInstance, HINSTANCE hPrevInstance, LPSTR
lpszCmdLine, int nCmdShow) {
  WNDCLASS w;
  w.lpszClassName = ProgName;
  w.hInstance = hInstance;
  w.lpfnWndProc = WndProc;
  w.hCursor = LoadCursor(NULL, IDC_ARROW);
  w.hIcon = 0;
  w.lpszMenuName = 0;
  w.hbrBackground = WHITE_BRUSH;
  w.style = CS_HREDRAW | CS_VREDRAW;
  w.cbClsExtra = 0;
  w.cbWndExtra = 0;
  if (!RegisterClass(&w)) {
    return 0;
  }
  HWND hWnd;
  MSG lpMsg;
  hWnd = CreateWindow(ProgName,
                      (LPCSTR) "Lab 5. by Daniil Timofeev from IM-22",
                      WS_OVERLAPPEDWINDOW,
                      100,
                      100,
                      1500,
                      750,
                      (HWND) NULL,
                      (HMENU) NULL,
                      (HINSTANCE) hInstance,
                      (HINSTANCE) NULL);
  ShowWindow(hWnd, nCmdShow);
  while (GetMessage(&lpMsg, hWnd, 0, 0)) {
    TranslateMessage(&lpMsg);
    DispatchMessage(&lpMsg);
  }
  return (lpMsg.wParam);
}

LRESULT CALLBACK WndProc(HWND hWnd, UINT messg, WPARAM wParam, LPARAM lParam)
{
  HDC hdc;
  PAINTSTRUCT ps;
```

```
  HWND ButtonForDFS;
  HWND ButtonForBFS;
  const int numVertices = vertices;
  int state = 0;

  double **T = randm(vertices);
  double coefficient = 1.0 - 0.01 - 0.005 - 0.15;
  double **A = mulmr(coefficient, T, vertices);


  int* visitedVertex = malloc(vertices * sizeof(int));
  int* depthVertices = malloc(vertices * sizeof(int));
  int* queue = malloc(vertices * sizeof(int));
  int birthVertex = findStartVertex(A, vertices);
  double** dfsTree = createMatrix(vertices);
  double** bfsTree = createMatrix(vertices);
  chargeWithZero(dfsTree, vertices);
  chargeWithZero(bfsTree, vertices);

  runDfsForNotVisitedVertices(birthVertex, A, visitedVertex, 0,
depthVertices, dfsTree);
  breadthFirstSearch(A, birthVertex, queue, bfsTree);


  switch (messg) {
    case WM_CREATE: {
      ButtonForDFS = CreateWindow(
              (LPCSTR) "BUTTON",
              (LPCSTR) "Next Step: DFS",
              WS_TABSTOP | WS_VISIBLE | WS_CHILD | BS_DEFPUSHBUTTON,
              700,
              30,
              160,
              50,
              hWnd,
              (HMENU) IDC_BUTTON,
              (HINSTANCE) GetWindowLongPtr(hWnd, GWLP_HINSTANCE),
              NULL);
      ButtonForBFS = CreateWindow(
              (LPCSTR) "BUTTON",
              (LPCSTR) "Next Step: BFS",
              WS_TABSTOP | WS_VISIBLE | WS_CHILD | BS_DEFPUSHBUTTON,
              700,
              600,
              160,
              50,
              hWnd,
              (HMENU) IDC_BUTTON2,
              (HINSTANCE) GetWindowLongPtr(hWnd, GWLP_HINSTANCE),
              NULL);
      return 0;
    }
    case WM_COMMAND: {
      switch (LOWORD(wParam)) {

        case IDC_BUTTON:
          state = 0;
          if (dfsIterationAmount < numVertices) dfsIterationAmount++;
          InvalidateRect(hWnd, NULL, FALSE);
          break;

        case IDC_BUTTON2:
          state = 1;
          if (bfsIterationAmount < numVertices) bfsIterationAmount++;
```

```
            InvalidateRect(hWnd, NULL, FALSE);
            break;
        }
    }
    case WM_PAINT :
      hdc = BeginPaint(hWnd, &ps);
      SetGraphicsMode(hdc, GM_ADVANCED);
      HPEN BPen = CreatePen(PS_SOLID, 2, RGB(50, 0, 255));
      HPEN KPen = CreatePen(PS_SOLID, 1, RGB(20, 20, 5));
      HPEN GPen = CreatePen(PS_SOLID, 2, RGB(0, 255, 0));
      HPEN OPen = CreatePen(PS_SOLID, 2, RGB(255, 165, 0));
      HPEN PPen = CreatePen(PS_SOLID, 2, RGB(255, 0, 255));
      HPEN NoPen = CreatePen(PS_NULL, 0, RGB(0, 0, 0));
      SelectObject(hdc, NoPen);
      Rectangle(hdc, 0, 0, 670, 700);


      char *nn[vertices] = {"1", "2", "3", "4", "5", "6", "7", "8", "9",
"10\0", "11\0", "12\0"};

      struct coordinates coordinates;

      double circleRadius = 200;
      double vertexRadius = circleRadius / 12;

      double loopRadius = vertexRadius;
      double dtx = vertexRadius / 2.5;

      double circleCenterX = 370;
      double circleCenterY = 360;


      double angleAlpha = 2.0 * M_PI / (double) vertices;
      for (int i = 0; i < vertices; i++) {

        double sinAlpha = sin(angleAlpha * (double) i);
        double cosAlpha = cos(angleAlpha * (double) i);
        coordinates.nx[i] = circleCenterX + circleRadius * sinAlpha;
        coordinates.ny[i] = circleCenterY - circleRadius * cosAlpha;
        coordinates.loopX[i] = circleCenterX + (circleRadius + loopRadius) *
sinAlpha;
        coordinates.loopY[i] = circleCenterY - (circleRadius + loopRadius) *
cosAlpha;

      }

      int initialXOofRandMatrix = 750;
      int initialYofRandMatrix = 150;
      double** dfsDetour = createTraversalMatrix(depthVertices);
      double** bfsDetour = createTraversalMatrix(queue);
      TextOut(hdc, initialXOofRandMatrix, initialYofRandMatrix, (LPCSTR)
L"Initial Matrix", 28);
      printMatrix(A, vertices, initialXOofRandMatrix, initialYofRandMatrix,
hdc);

      TextOut(hdc, initialXOofRandMatrix+200, initialYofRandMatrix, (LPCSTR)
L"DFS Relativity", 28);
      printMatrix(dfsDetour, vertices, initialXOofRandMatrix + 200,
initialYofRandMatrix, hdc);
      TextOut(hdc, initialXOofRandMatrix+400, initialYofRandMatrix, (LPCSTR)
L"DFS Tree", 15);
      printMatrix(dfsTree, vertices, initialXOofRandMatrix + 400,
initialYofRandMatrix, hdc);
```

```
      TextOut(hdc, initialXOofRandMatrix+200, initialYofRandMatrix+250,
(LPCSTR) L"BFS Relativity", 28);
      printMatrix(bfsDetour, vertices, initialXOofRandMatrix + 200,
initialYofRandMatrix + 250, hdc);
      TextOut(hdc, initialXOofRandMatrix+400, initialYofRandMatrix+250,
(LPCSTR) L"BFS Tree", 15);
      printMatrix(bfsTree, vertices, initialXOofRandMatrix + 400,
initialYofRandMatrix + 250, hdc);









      SelectObject(hdc, GetStockObject(HOLLOW_BRUSH));
      SelectObject(hdc, KPen);
      depictDirectedGraph(circleCenterX, circleCenterY, circleRadius,
vertexRadius, loopRadius, angleAlpha,
                          coordinates, A, KPen, GPen, hdc);


        SelectObject(hdc, BPen);
        SelectObject(hdc, GetStockObject(DC_BRUSH));
        SetDCBrushColor(hdc, RGB(204, 204, 255));
        SetBkMode(hdc, TRANSPARENT);

        for (int i = 0; i < vertices; ++i) {
          Ellipse(hdc, coordinates.nx[i] - vertexRadius, coordinates.ny[i] -
vertexRadius,
                  coordinates.nx[i] + vertexRadius, coordinates.ny[i] +
vertexRadius);
          TextOut(hdc, coordinates.nx[i] - dtx, coordinates.ny[i] -
vertexRadius / 2, nn[i], 2);
        }

        SelectObject(hdc, OPen);
        SetDCBrushColor(hdc, RGB(255, 165, 0));

      if (state == 0) {
        double** modified = createMatrix(numVertices);
        chargeWithZero(modified,numVertices);
        for (int i = 0; i < dfsIterationAmount; ++i) {
          constructSearchMatrix(dfsTree,depthVertices[i], modified);
          depictDirectedGraph(circleCenterX, circleCenterY, circleRadius,
vertexRadius, loopRadius, angleAlpha,
                              coordinates, modified, OPen, GPen, hdc);
          Ellipse(hdc, coordinates.nx[depthVertices[i]] - vertexRadius,
coordinates.ny[depthVertices[i]] - vertexRadius,
                  coordinates.nx[depthVertices[i]] + vertexRadius,
coordinates.ny[depthVertices[i]] + vertexRadius);
        }

        for (int i = 0; i < dfsIterationAmount; i++)
        {
          wchar_t buffer[5];
          swprintf(buffer, 5, L"%d", depthVertices[i] + 1);
          TextOut(hdc, coordinates.nx[depthVertices[i]] - dtx,
coordinates.ny[depthVertices[i]] - vertexRadius / 2, buffer, 3);
        }

        freeMatrix(modified,numVertices);
```

```
      }

      SelectObject(hdc, PPen);
      SetDCBrushColor(hdc, RGB(255, 0, 255));

      if (state == 1) {
        double** modified = createMatrix(numVertices);
        chargeWithZero(modified,numVertices);

        for (int i = 0; i < bfsIterationAmount; ++i) {
          constructSearchMatrix(bfsTree,queue[i], modified);
          depictDirectedGraph(circleCenterX, circleCenterY, circleRadius,
vertexRadius, loopRadius, angleAlpha,
                              coordinates, modified, BPen, GPen, hdc);

          Ellipse(hdc, coordinates.nx[queue[i]] - vertexRadius,
coordinates.ny[queue[i]] - vertexRadius,
                  coordinates.nx[queue[i]] + vertexRadius,
coordinates.ny[queue[i]] + vertexRadius);
        }

        for (int i = 0; i < bfsIterationAmount; i++)
        {
          wchar_t buffer[5];
          swprintf(buffer, 5, L"%d", queue[i] + 1);
          TextOut(hdc, coordinates.nx[queue[i]] - dtx,
coordinates.ny[queue[i]] - vertexRadius / 2, buffer, 3);
        }
        freeMatrix(modified,numVertices);

      }



        EndPaint(hWnd, &ps);

        freeMatrix(A, vertices);
        free(queue);
        free(depthVertices);
        free(visitedVertex);
        freeMatrix(dfsDetour, vertices);
        freeMatrix(bfsDetour, vertices);
        freeMatrix(dfsTree, vertices);
        freeMatrix(bfsTree, vertices);

        case WM_DESTROY:
          PostQuitMessage(0);
        break;
        default:
          return (DefWindowProc(hWnd, messg, wParam, lParam));

  }
  return 0;
}
```

Файл *components*.c :

```
#include <stdio.h>
#include <stdlib.h>
#define vertices 12

void typeMatrix(double **matrix) {
```

```
  const int number = vertices;
  for (int i = 0; i < number; i++) {
    for (int j = 0; j < number; j++) {
      printf("%.0lf  ", matrix[i][j]);
    }
    printf("\n");
  }
}


double **randm(int n) {
  srand(2220);
  double **matrix = (double **) malloc(sizeof(double *) * n);
  for (int i = 0; i < n; i++) {
    matrix[i] = (double *) malloc(sizeof(double) * n);
  }
  for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
      matrix[i][j] = (double) (rand() * 2.0) / (double) RAND_MAX;
    }
  }
  return matrix;

}

double** createMatrix(int n) {
  double **matrix = (double **) malloc(n * sizeof(double *));
  for (int i = 0; i < n; i++) {
    matrix[i] = (double *) malloc(n * sizeof(double));
  }
  return matrix;
}

void chargeWithZero(double** matrix, int n)
{
  for (int i = 0; i < n; i++)
  {
    for (int j = 0; j < n; j++)
    {
      matrix[i][j] = 0.;
    }
  }
}

double **mulmr(double coef, double **matrix, int n) {
  for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
      matrix[i][j] *= coef;
      matrix[i][j] = matrix[i][j] < 1 ? 0 : 1;
    }
  }
  return matrix;
}



void freeMatrix(double **matrix, int n) {
  for (int i = 0; i < n; ++i) {
    free(matrix[i]);
  }
  free(matrix);
}
```

```
void depthFirstSearch(double** adjacencyMatrix, int currentVertex, int*
visited, int* depthVertices, double** tree, int* numVisited) {
  const int number = vertices;
  visited[currentVertex] = 1;
  depthVertices[(*numVisited)] = currentVertex;
  (*numVisited)++;

  for (int neighborVertex = 0; neighborVertex < number; ++neighborVertex) {
    if (adjacencyMatrix[currentVertex][neighborVertex] == 1 &&
!visited[neighborVertex]) {

      tree[currentVertex][neighborVertex] = 1;
      depthFirstSearch(adjacencyMatrix, neighborVertex, visited,
depthVertices, tree, numVisited);

    }
  }
}

void breadthFirstSearch(double** adjacencyMatrix, int startVertex, int*
queue, double** tree) {
  const int number = vertices;
  int visited[number];
  for (int i = 0; i < number; i++)
  {
    visited[i] = 0;
  }
  int queueStart = 0;
  int queueFinish = -1;

  queue[++queueFinish] = startVertex;
  visited[startVertex] = 1;

  while (queueStart <= queueFinish) {
    int currentVertex = queue[queueStart++];
    for (int neighborVertex = 0; neighborVertex < number; neighborVertex++) {
      if (adjacencyMatrix[currentVertex][neighborVertex] == 1 &&
visited[neighborVertex] == 0)
      {
        tree[currentVertex][neighborVertex] = 1;
        queue[++queueFinish] = neighborVertex;
        visited[neighborVertex] = 1;
      }
    }
  }
}

int findStartVertex(double** matrix, int n) {
  int* outgoingCounts = (int*)calloc(n, sizeof(int));


  for (int i = 0; i < n; ++i) {
    for (int j = 0; j < n; ++j) {
      if (matrix[i][j] == 1) {
        outgoingCounts[i]++;
      }
    }
  }


  for (int i = 0; i < n; ++i) {
    if (outgoingCounts[i] > 0) {
      free(outgoingCounts);
      return i;
```

```
    }
  }

  free(outgoingCounts);
  return -1;
}

void constructSearchMatrix(double** graph, int sourceVertex, double**
searchMatrix) {
  const int number = vertices;

  for (int i = 0; i < number; ++i) {
    if (graph[i][sourceVertex]) searchMatrix[i][sourceVertex] = 1;
  }
}

double** createTraversalMatrix(const int* arr) {


  double** traversalMatrix = createMatrix(vertices);
  chargeWithZero(traversalMatrix, vertices);


  for (int i = 0; i < vertices; i++)
  {
    traversalMatrix[arr[i]][i] = 1.0;
  }

  return traversalMatrix;
}

void runDfsForNotVisitedVertices(int currentVertex, double** adjacencyMatrix,
                                 int* visited, int amount, int*
depthVertices, double** graph ) {

  const int number = vertices;

  for (int i = 0; i < number; ++i) {
    visited[i] = 0;
  }

  for (int i = 0; i < number; ++i) {
    if (visited[i] == 0) {
      depthFirstSearch(adjacencyMatrix, currentVertex, visited,
depthVertices,graph, &amount);
    }

  }

}
```

Матриця суміжності

```
Initial Matrix

0 0 1 0 0 0 0 1 1 0 0 1
1 0 0 0 0 0 0 0 0 1 1 0
1 0 0 0 0 0 0 0 1 0 1 1
1 0 1 1 1 0 1 1 1 0 1 1
1 1 0 1 0 1 1 0 0 0 0 0
1 0 1 0 0 0 0 0 0 1 1 1
0 1 1 0 1 0 0 0 1 1 0 0
0 1 0 0 0 0 0 1 0 0 1 1
1 1 0 1 1 0 0 1 0 0 1 0
0 0 1 0 1 0 1 0 0 0 0 0
0 0 1 1 0 1 0 0 1 0 1 0
1 1 0 1 0 1 0 0 0 1 1 0
```

Пошук у глибину

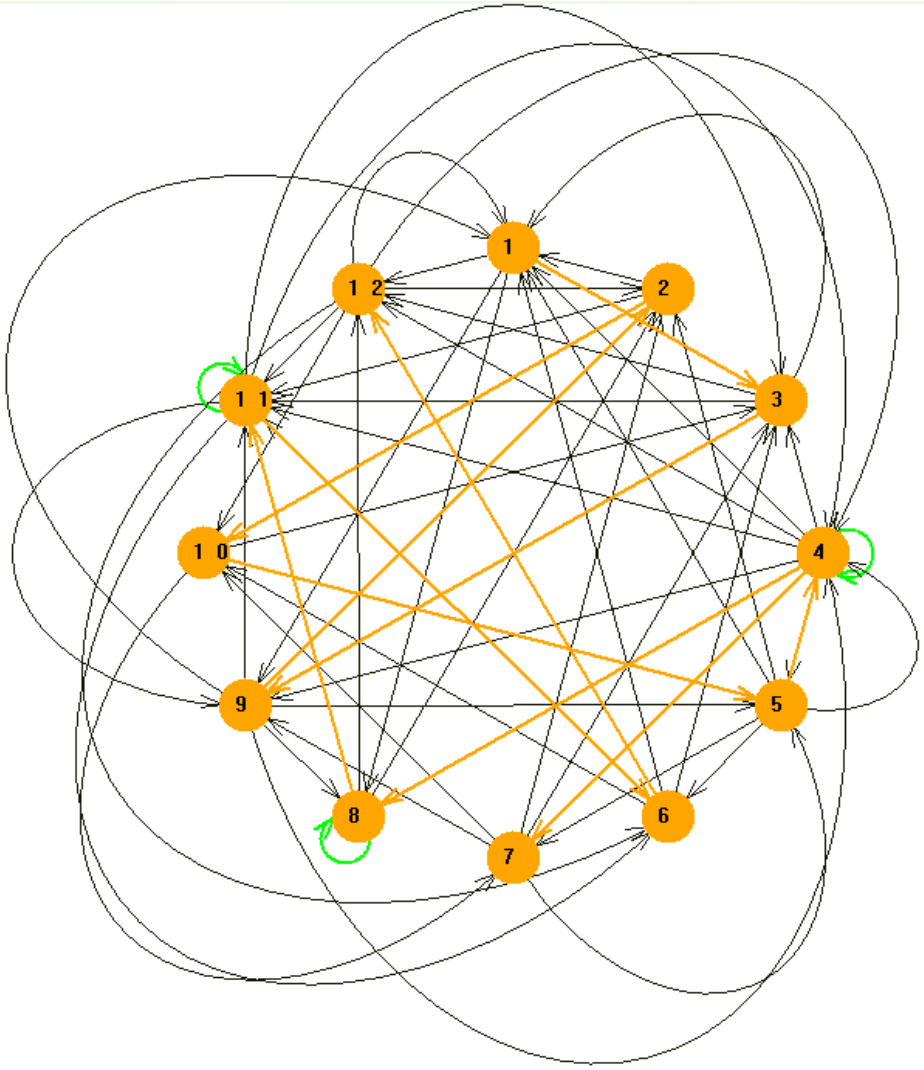
Матриця дерева обходу, матриця відповідності, зображення дерева :

```
D F S   T r e e

0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0
0 0 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 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 0 0 1 0
0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0
```

```
D F S   R e l a t i v i t y

1 0 0 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 0 0
0 0 0 0 0 0 1 0 0 0 0 0
0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 0
0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0
0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 1
```



Пошук у ширину

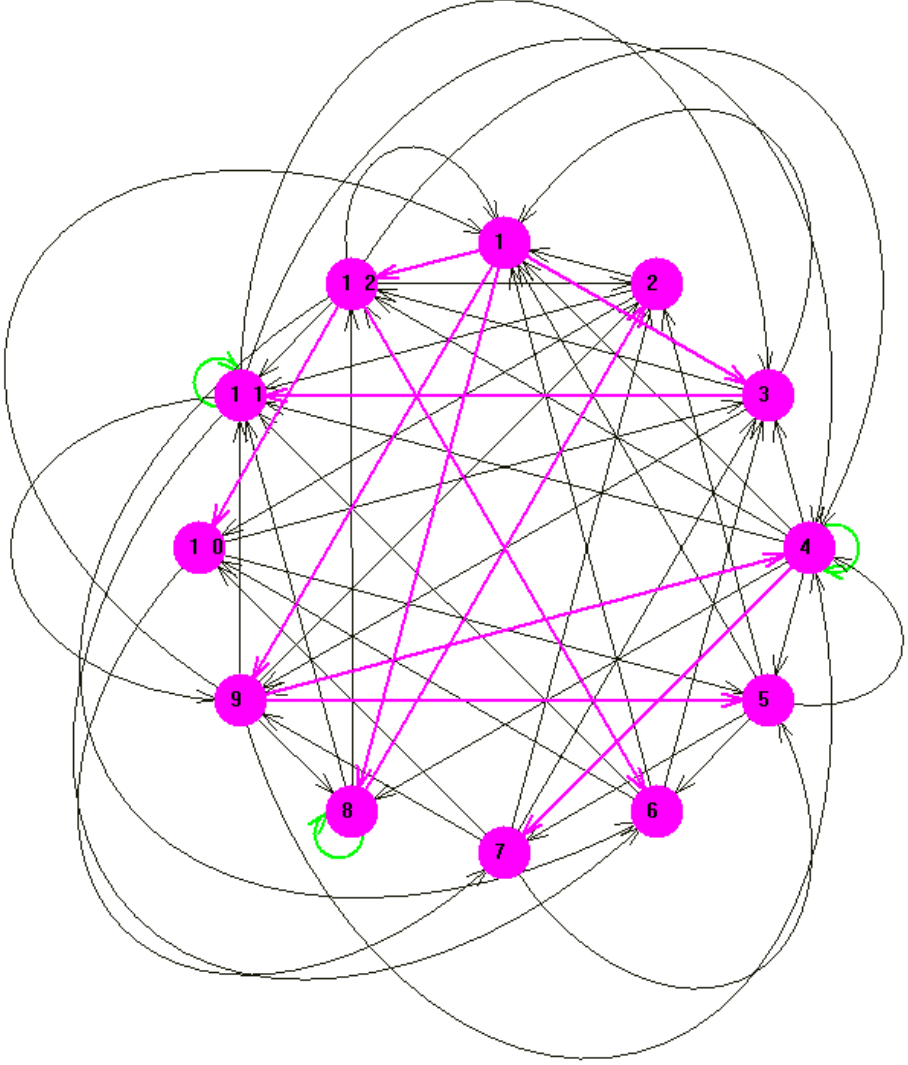
Матриця дерева обходу, матриця відповідності, зображення дерева :

```
B F S   T r e e

0 0 1 0 0 0 1 1 0 0 1
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0
0 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 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0
0 0 0 1 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 1 0 0 0 1 0
```

```
B F S   R e l a t i v i t y

1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 1
0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 0
0 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0
```


1
1 2
2
1 1
3
1 0
4
9
5
8
6
7