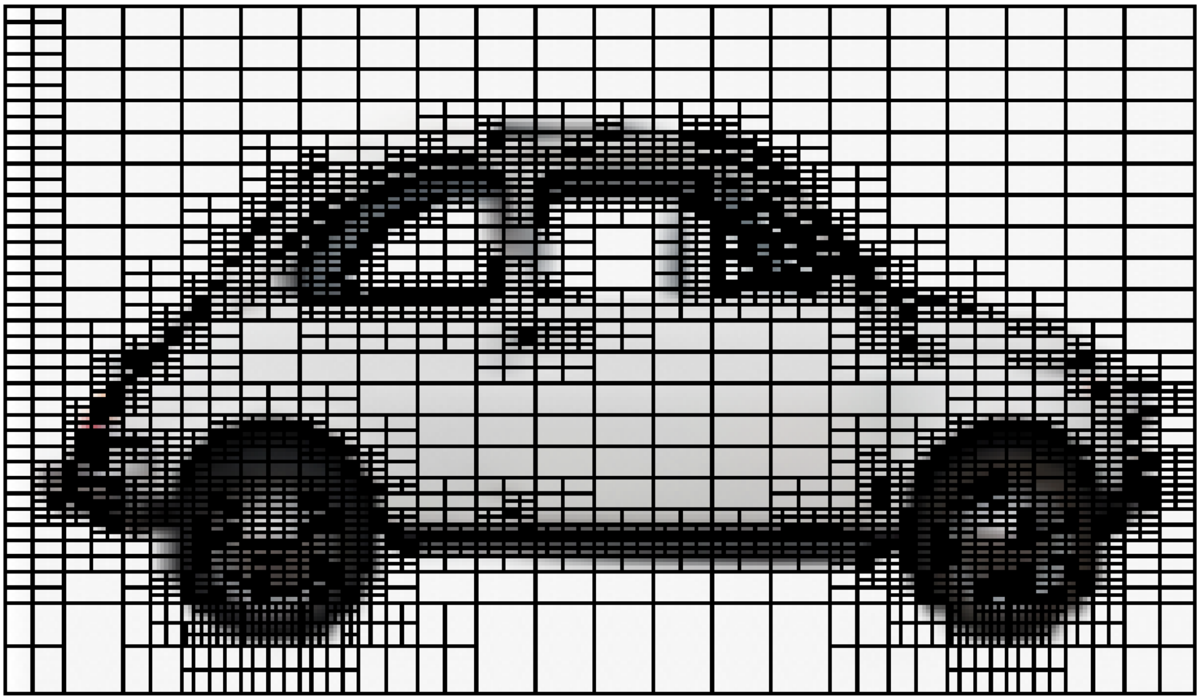
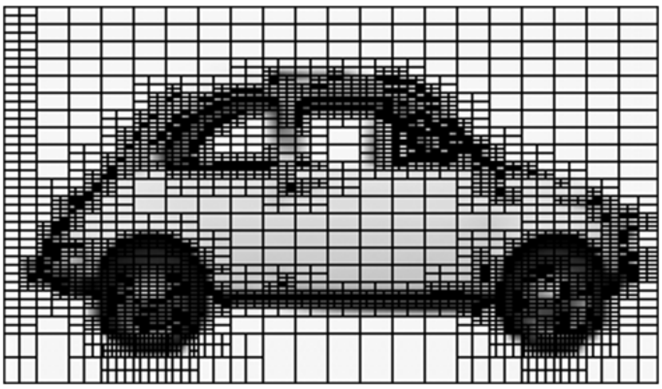
[CAD CAE] Lab 4

Oryginalne zdjęcie

Bitmap_h



Bitmap_h_gray



Zmodyfikowany kod

```
% This is a implementation of h-adaptive bitmap projection.
%
% How to use
%
% bitmap(filename as a string, number of elements along x axis, , number of elements along y axis, maximum relative error, maximum lev
%
% Examples
%
% bitmap("mp.JPG", 10,10,0.1,3,false)
% bitmap("basket.JPG", 20,20,0.5,1,true)
function bitmap_h_gray(filename,elementsx,elementsy,maxerror,max_refinement_level,color_edges_black)
tic
% read image from file
XX = imread(filename);

% exctract red, green and blue components
RR = XX(:,:,1);
GG = XX(:,:,2);
BB = XX(:,:,3);
Gray = 0.299 * RR + 0.587 * GG + 0.114 * BB;

% read size of image
ix = size(XX,1);
iy = size(XX,2);

% global count of vertexes
total_vertexes = 0;
% global count of elements
total_elements = 0;

% element structure contains:
% * vertices - organized as followed:
%
% ul - ur
% |    |
% dl - dr
%
% ul - up-left
% ur - up-right
% dl - down-left
% dr - down-right
%
% * neighbours (elements) ogranized as followed
% there can be up to two neighbours on each edge
% default neighours (if there is one neighbour) are:
% eul, elu, eru, edl
%
%      eul eur
%      ___ ___
% elu |       | eru
%     |       |
% eld |___ ___| erd
%      edl edr
%
% eul - element-up-left
% eur - element-up-rgiht
% elu - element-left-up
% eld - element-left-down
% eru - element-right-up
% erd - element-right-down
% edl - element-down-left
% edr - element-down-right
%
% * active - we don't delete inactive elements, rather tag them as inactive
% * index - index of element in global elements table
%
elements = struct('dl',{},'ul',{},'dr',{},'ur',{},'active',{},'elu',{},'eld',{},'edl',{},'edr',{},'eul',{},'eur',{},'eru',{},'erd',{},
%
% vertex data structure contains
% * x and y coordinates
% * gray - gray component
% * index - index of vertex in global vertexes table
% * real - false if vertes is hanging node and has interpolate gray component
%
vertexes = struct('x',{},'y',{},'gray',{},'index',{},'real',{});

% initialize unbroken mesh
init_mesh();

redo_error_test = true;
refinemenet_level = 0;

% repeat until we match maximum local estimation error or maximum refinemenet level
while (redo_error_test && (refinemenet_level < max_refinement_level))
  redo_error_test = false;
```

```
% loop through elements
  for i=1:total_elements
% check only active elements
    if (elements(i).active)
% estimate realtive interpolation error in gray component
      gray_error = estimate_error(i);
% if the error is higher than our maximum -> break element and repeat entire loop
      if (gray_error >= maxerror)
        redo_error_test = true;
        break_element(i);
      end
    end
  end
  refinemenet_level = refinemenet_level + 1;
end

% interpolate all active elements - recreate bitmap red green and blue compoments
for i=1:total_elements
  if (elements(i).active)
    interpolate_elem(i,color_edges_black);
  end
end

% display image
% imshow(RGB);
toc
imwrite(Gray, strcat("gray_", filename))


% create vertex (non hanging node)
function index=create_vertex(x,y)
  vert.x = x;
  vert.y = y;
  vert.gray = Gray(x,y);
  total_vertexes = total_vertexes + 1;
  vert.index = total_vertexes;
  vert.real = true;
  vertexes(total_vertexes) = vert;
  index = total_vertexes;
end


% create vertex (hanging node)
function index=create_vertex_gray(x,y,gray)
  vert.x = x;
  vert.y = y;
  vert.gray = gray;
  total_vertexes = total_vertexes + 1;
  vert.index = total_vertexes;
  vert.real = false;
  vertexes(total_vertexes) = vert;
  index = total_vertexes;
end


% update vertex - when hanging node becomes non-hanging node
function vert_update(index)
  vert = vertexes(index);
  vert.gray = Gray(vert.x,vert.y);
  vert.real = true;
  vertexes(index) = vert;
end


% create initial element
function element=create_element(v1,v2,v3,v4)
  element.dl = v1;
  element.ul = v2;
  element.dr = v3;
  element.ur = v4;

  element.active = true;

% set all neighbours to null
  element.elu = 0;
  element.eld = 0;
  element.edl = 0;
  element.edr = 0;
  element.eul = 0;
  element.eur = 0;
  element.eul = 0;
  element.eru = 0;
  element.erd = 0;

  total_elements = total_elements + 1;
  element.index = total_elements;
end
```

```
% initialize mesh
function init_mesh()
%
% vertexes mapping
%
% v2 -> ul
% v4 -> ur
% v1 -> dl
% v3 -> dr
%
  elem_width = floor(ix / elementsx);
  elem_hight = floor(iy / elementsy);

  x = 0;
  y = 0;

% create all vertexes
  for i=0:elementsy-1
    for j=0:elementsx-1
      vertex = create_vertex(x+j*elem_width+1,y+1);
    end
    vertex = create_vertex(ix,y+1);
    y = y + elem_hight;
  end
  for j=0:elementsx-1
    vertex = create_vertex(x+j*elem_width+1,iy);
  end
  vertex = create_vertex(ix,iy);

% crete all elements
  for i=1:elementsy
    for j=1:elementsx
      v1 = (i-1)*elementsy+j + i-1;
      v3 = v1+1;
      v2 = i*elementsy+j+1 + i-1;
      v4 = v2+1;
      element = create_element(v1,v2,v3,v4);
      index = element.index;
% set neighbours for each element
      if(j~=1)
        element.elu = index-1;
      end
      if(j~=elementsx)
        element.eru = index+1;
      end
      if(i~=1)
        element.edl = index-elementsx;
      end
      if(i~=elementsy)
        element.eul = index+elementsx;
      end
      elements(index) = element;
    end
  end

end


% interpolate gray component for hanging node
% v1 and v2 are vertexes of given element on edges of broken edge
% v3 is interpolated vertex between v1 and v2
function v3=interpolate_rgb(v1,v2,element)
  elem = elements(element);
  width = vertexes(elem.dr).x - vertexes(elem.dl).x;
  hight = vertexes(elem.ul).y - vertexes(elem.dl).y;
  vert1 = vertexes(v1);
  vert2 = vertexes(v2);

  vert3.x = (vert1.x + vert2.x) /2;
  vert3.y = (vert1.y + vert2.y) /2;
  vert3.x = floor(vert3.x);
  vert3.y = floor(vert3.y);

  xx = vert3.x - vertexes(elem.dl).x;
  yy = vert3.y - vertexes(elem.dl).y;
  gray = inpoint(xx,yy,width,hight,elem);

  vert3.gray = gray;
  vert3.real = false;

  total_vertexes = total_vertexes + 1;
  vert3.index = total_vertexes;
  v3 = total_vertexes;
  vertexes(v3) = vert3;
end
```

```
% interpolate gray component of an element
function interpolate_elem(element,color_edges_black)
  elem = elements(element);
  width = vertexes(elem.dr).x - vertexes(elem.dl).x;
  hight = vertexes(elem.ul).y - vertexes(elem.dl).y;
  width = abs(width);
  hight = abs(hight);
  dlx = vertexes(elem.dl).x;
  dly = vertexes(elem.dl).y;

  for xx=0:width
    for yy=0:hight
      gray = inpoint(xx,yy,width,hight,elem);
      Gray(dlx+xx,dly+yy) = gray;
    end
  end

% create black edges on element if requested
  if (color_edges_black)
    for xx=0:width
      Gray(dlx+xx,dly) = 0;
      Gray(dlx+xx,dly+hight) = 0;
    end

    for yy=0:hight
      Gray(dlx,dly+yy) = 0;
      Gray(dlx+width,dly+yy) = 0;
    end
  end
end


% computes gray component of element in given point
function gray=inpoint(xx,yy,width,hight,elem)
  f1 = fi1(xx,yy);
  f2 = fi2(xx,yy);
  f3 = fi3(xx,yy);
  f4 = fi4(xx,yy);

  gray = vertexes(elem.dl).gray * f1;
  gray = gray + vertexes(elem.ul).gray * f2;
  gray = gray + vertexes(elem.dr).gray * f3;
  gray = gray + vertexes(elem.ur).gray * f4;
  gray = floor(gray);

% basis functions defined over element
  function ret=fi1(xx,yy)
    x = xx/width;
    y = yy/hight;
    ret = (1-x) * (1-y);
  end

  function ret=fi2(xx,yy)
    x = xx/width;
    y = yy/hight;
    ret = (1-x) * y;
  end

  function ret=fi3(xx,yy)
    x = xx/width;
    y = yy/hight;
    ret = x * (1-y);
  end

  function ret=fi4(xx,yy)
    x = xx/width;
    y = yy/hight;
    ret = x * y;
  end
end


% if neighbour is already bigger than element that we try to break - we should break it as well
function break_neighbours(index)
  element = elements(index);

  check_left();
  check_right();
  check_up();
  check_down();


  function check_left()
% no neighbours on the left
    if (element.elu == 0)
```

```
      return;
    end
% two neighbours on the left
    if(element.eld ~= 0)
      return;
    end
% only one neighbour on the left
    left = elements(element.elu);
    if (left.erd ~= 0)
% neighbour on the left has two neighbours on the right
      break_element(element.elu);
    end
  end

  function check_right()
% no neighbours on the right
    if (element.eru == 0)
      return;
    end
% two neighbours on the right
    if (element.erd ~= 0)
      return;
    end
% only one neighbour on the right
    right = elements(element.eru);
    if (right.eld ~= 0)
% neighbour on the right has two neighbours on the left
      break_element(element.eru);
    end
  end

  function check_up()
% no neighbours on the top
    if (element.eul == 0)
      return;
    end
% two neighbours on the top
    if (element.eur ~= 0)
      return;
    end
% only one neighbour on the top
    up = elements(element.eul);
    if (up.edr ~= 0)
% neighbour on the top has two neighbours on the bottom
      break_element(element.eul);
    end
  end

  function check_down()
% no neighbours on the bottom
    if (element.edl == 0)
      return;
    end
% two neighbours on the bottom
    if (element.edr ~= 0)
      return;
    end
% only one neighbour on the bottom
    down = elements(element.edl);
    if (down.eur ~= 0)
% neighbour on the bottom has two neighbours on the top
      break_element(element.edl);
    end
  end
end


% breaking element
function break_element(index)

  element = elements(index);
  if (~element.active)
    disp('error!!!');
  end
  break_neighbours(index);
  element = elements(index);
% vertexes of element are organized as followed
%
% ul - ur
% |    |
% dl - dr
%
% they are mapped to local vertices
%
% v2 - v4
% |  e  |
% v1 - v3
```

```
%
%
% after breaking element vertices and new elements are organized as followed
%
% v2 - v9 - v4
%  | e2 | e4 |
% v6 - v7 - v8
%  | e1 | e3 |
% v1 - v5 - v3
%
%
% e  -> e2 e4
%       e1 e3
%

  v1 = element.dl;
  v2 = element.ul;
  v3 = element.dr;
  v4 = element.ur;

  v5=0;
  v6=0;
  v7=0;
  v8=0;
  v9=0;

% if we have two neighbours left
  if (element.eld ~= 0)
    eld = elements(element.eld);
    v6 = eld.ur;
    vert_update(v6);
% if we have unbroken neighbour left
  else
    v6 = interpolate_rgb(v1,v2,index);
  end
  if (element.elu == 0)
    vert_update(v6);
  end

% if we have two neighbours right
  if (element.erd ~= 0)
    erd = elements(element.erd);
    v8 = erd.ul;
    vert_update(v8);
% if we have unbroken neighbour right
  else
    v8 = interpolate_rgb(v3,v4,index);
  end
  if (element.eru == 0)
    vert_update(v8);
  end

% if we have two neighbours up
  if (element.eur ~= 0)
    eur = elements(element.eur);
    v9 = eur.dl;
    vert_update(v9)
% if we have unbroken neighbour up
  else
    v9 = interpolate_rgb(v2,v4,index);
  end
  if (element.eul == 0)
    vert_update(v9);
  end

% if we have two neighbours down
  if (element.edr ~= 0)
    edr = elements(element.edr);
    v5 = edr.ul;
    vert_update(v5);
% if we have unbroken neighbour down
  else
    v5 = interpolate_rgb(v1,v3,index);
  end
  if (element.edl == 0)
    vert_update(v5);
  end

  x = vertexes(v5).x;
  y = vertexes(v6).y;

  v7 = create_vertex(x,y);

  element.active = false;
  elements(element.index) = element;

  e1 = create_element(v1,v6,v5,v7);
```

```
  e2 = create_element(v6,v2,v7,v9);
  e3 = create_element(v5,v7,v3,v8);
  e4 = create_element(v7,v9,v8,v4);

% set neighbours between new elements
  e1.eru = e3.index;
  e1.eul = e2.index;
  e2.edl = e1.index;
  e2.eru = e4.index;
  e3.elu = e1.index;
  e3.eul = e4.index;
  e4.elu = e2.index;
  e4.edl = e3.index;

% set neighbours between new and old elements
  e1.edl = element.edl;
  if (element.edl ~= 0)
    edl = elements(element.edl);
    edl.eul = e1.index;
    elements(edl.index) = edl;
  end
  if (element.edr ~= 0)
    e3.edl = element.edr;
    edr = elements(element.edr);
    edr.eul = e3.index;
    elements(edr.index) = edr;
  else
    e3.edl = element.edl;
    if (element.edl ~= 0)
      edl = elements(element.edl);
      edl.eur = e3.index;
      elements(edl.index) = edl;
    end
  end

  e2.elu = element.elu;
  if (element.elu ~= 0)
    elu = elements(element.elu);
    elu.eru = e2.index;
    elements(elu.index) = elu;
  end
  if (element.eld ~= 0)
    e1.elu = element.eld;
    eld = elements(element.eld);
    eld.eru = e1.index;
    elements(eld.index) = eld;
  else
    e1.elu = element.elu;
    if (element.elu ~= 0)
      elu = elements(element.elu);
      elu.erd = e1.index;
      elements(elu.index) = elu;
    end
  end

  e2.eul = element.eul;
  if (element.eul ~= 0)
    eul = elements(element.eul);
    eul.edl = e2.index;
    elements(eul.index) = eul;
  end
  if (element.eur ~= 0)
    e4.eul = element.eur;
    eur = elements(element.eur);
    eur.edl = e4.index;
    elements(eur.index) = eur;
  else
    e4.eul = element.eul;
    if (element.eul ~= 0)
      eul = elements(element.eul);
      eul.edr = e4.index;
      elements(eul.index) = eul;
    end
  end

  e4.eru = element.eru;
  if (element.eru ~= 0)
    eru = elements(element.eru);
    eru.elu = e4.index;
    elements(eru.index) = eru;
  end
  if (element.erd ~= 0)
    e3.eru = element.erd;
    erd = elements(element.erd);
    erd.elu = e3.index;
    elements(erd.index) = erd;
  else
```

```
    e3.eru = element.eru;
    if (element.eru ~= 0)
      eru = elements(element.eru);
      eru.eld = e3.index;
      elements(eru.index) = eru;
    end
  end

  elements(e4.index) = e4;
  elements(e3.index) = e3;
  elements(e2.index) = e2;
  elements(e1.index) = e1;
end


% estimate relative error of interpolation over given element
function error_gray=estimate_error(index)
  element = elements(index);
  dl = element.dl;
  ul = element.ul;
  dr = element.dr;
  ur = element.ur;

  xl = vertexes(dl).x;
  yd = vertexes(dl).y;
  xr = vertexes(ur).x;
  yu = vertexes(ur).y;

  elementWidth = xr - xl;
  elementHeigth = yu - yd;

% interpolate using L2 norm and Gaussian quadrature rule
  x1 = elementWidth/2.0 - elementWidth / (sqrt(3.0) * 2.0);
  x2 = elementWidth/2.0 + elementWidth / (sqrt(3.0) * 2.0);
  y1 = elementHeigth/2.0 - elementHeigth / (sqrt(3.0) * 2.0);
  y2 = elementHeigth/2.0 + elementHeigth / (sqrt(3.0) * 2.0);

  x1 = floor(x1);
  x2 = floor(x2);
  y1 = floor(y1);
  y2 = floor(y2);

  gray1=inpoint(x1,y1,elementWidth,elementHeigth,element);
  gray2=inpoint(x1,y2,elementWidth,elementHeigth,element);
  gray3=inpoint(x2,y1,elementWidth,elementHeigth,element);
  gray4=inpoint(x2,y2,elementWidth,elementHeigth,element);

  gray1 = gray1 - Gray(x1+xl,y1+yd);
  gray2 = gray2 - Gray(x1+xl,y2+yd);
  gray3 = gray3 - Gray(x2+xl,y1+yd);
  gray4 = gray4 - Gray(x2+xl,y2+yd);

  error_gray = gray1*gray1 + gray2*gray2 + gray3*gray3 + gray4*gray4;
  error_gray = double(error_gray);
  error_gray = sqrt(error_gray) * 100.0 / (255.0 * 2.0);
end



end
```