ImagesToLARModel, a tool for creation of three-dimensional models from a stack of images

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Abstract

This is the abstract (we will use LAR [CL13])

Contents

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2 Exporting the library

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```
module ImagesToLARModel
"""
Main module for the library. It starts conversion
taking configuration parameters
"""
require(string(Pkg.dir("ImagesToLARModel/src"), "/imagesConvertion.jl"))

import JSON
import ImagesConvertion

using Logging

export convertImagesToLARModel

function loadConfiguration(configurationFile)
  """
  load parameters from JSON file

  configurationFile: Path of the configuration file
  """

  configuration = JSON.parse(configurationFile)

  DEBUG_LEVELS = [DEBUG, INFO, WARNING, ERROR, CRITICAL]

  return configuration["inputDirectory"], configuration["outputDirectory"], configuration["bes
        configuration["nx"], configuration["ny"], configuration["nz"],
        DEBUG_LEVELS[configuration["DEBUG_LEVEL"]]

end

function convertImagesToLARModel(configurationFile)
  """
  Start convertion of a stack of images into a 3D model
  loading parameters from a JSON configuration file

  configurationFile: Path of the configuration file
  """
  inputDirectory, outputDirectory, bestImage, nx, ny, nz, DEBUG_LEVEL = loadConfiguration(open
  convertImagesToLARModel(inputDirectory, outputDirectory, bestImage, nx, ny, nz, DEBUG_LEVEL)
end
```

```
    function convertImagesToLARModel(inputDirectory, outputDirectory, bestImage,
                                     nx, ny, nz, DEBUG_LEVEL = INFO)
      """
      Start convertion of a stack of images into a 3D model

      inputDirectory: Directory containing the stack of images
      outputDirectory: Directory containing the output
      bestImage: Image chosen for centroids computation
      nx, ny, nz: Border dimensions (Possibly the biggest power of two of images dimensions)
      DEBUG_LEVEL: Debug level for Julia logger. It can be one of the following:
        - DEBUG
        - INFO
        - WARNING
        - ERROR
        - CRITICAL
      """
      # Create output directory
      try
        mkpath(outputDirectory)
      catch
      end

      Logging.configure(level=DEBUG_LEVEL)
      ImagesConvertion.images2LARModel(nx, ny, nz, bestImage, inputDirectory, outputDirectory)
    end
    end
    ◇
```

"src/imagesConvertion.jl" 4≡

```
    module ImagesConvertion

    require(string(Pkg.dir("ImagesToLARModel/src"), "/generateBorderMatrix.jl"))
    require(string(Pkg.dir("ImagesToLARModel/src"), "/pngStack2Array3dJulia.jl"))
    require(string(Pkg.dir("ImagesToLARModel/src"), "/lar2Julia.jl"))
    require(string(Pkg.dir("ImagesToLARModel/src"), "/model2Obj.jl"))

    import GenerateBorderMatrix
    import PngStack2Array3dJulia
    import Lar2Julia
    import Model2Obj

    import JSON
```

```
using PyCall
@pyimport scipy.sparse as Pysparse

using Logging

export images2LARModel

"""
This is main module for converting a stack
of images into a 3d model
"""

function images2LARModel(nx, ny, nz, bestImage, inputDirectory, outputDirectory)
  """
  Convert a stack of images into a 3d model
  """

  info("Starting model creation")

  numberOfClusters = 2 # Number of clusters for
                       # images segmentation

  info("Moving images into temp directory")
  try
    mkdir(string(outputDirectory, "TEMP"))
  catch
  end

  tempDirectory = string(outputDirectory,"TEMP/")

  newBestImage = PngStack2Array3dJulia.convertImages(inputDirectory, tempDirectory, bestImage)

  imageWidth, imageHeight = PngStack2Array3dJulia.getImageData(string(tempDirectory,newBestIma
  imageDepth = length(readdir(tempDirectory))

  # Computing border matrix
  info("Computing border matrix")
  try
    mkdir(string(outputDirectory, "BORDERS"))
  catch
  end
  borderFilename = GenerateBorderMatrix.getOriented3BorderPath(string(outputDirectory, "BORDER

  # Starting images convertion and border computation
  info("Starting images convertion")
```

```
  startImageConvertion(tempDirectory, newBestImage, outputDirectory, borderFilename,
                       imageHeight, imageWidth, imageDepth,
                       nx, ny, nz,
                       numberOfClusters)

end


function startImageConvertion(sliceDirectory, bestImage, outputDirectory, borderFilename,
                              imageHeight, imageWidth, imageDepth,
                              imageDx, imageDy, imageDz,
                              numberOfClusters)
  """
  Support function for converting a stack of images into a model

  sliceDirectory: directory containing the image stack
  imageForCentroids: image chosen for centroid computation
  """


  # Create clusters for image segmentation
  info("Computing image centroids")
  debug("Best image = ", bestImage)
  centroidsCalc = PngStack2Array3dJulia.calculateClusterCentroids(sliceDirectory, bestImage, nu
  debug(string("centroids = ", centroidsCalc))

  try
    mkdir(string(outputDirectory, "BORDERS"))
  catch
  end
  debug(string("Opening border file: ", "border_", imageDx, "-", imageDy, "-", imageDz, ".json
  boundaryMat = getBorderMatrix(string(outputDirectory,"BORDERS/","border_", imageDx, "-",
                                       imageDy, "-", imageDz, ".json"))
  beginImageStack = 0
  endImage = beginImageStack

  info("Converting images into a 3d model")
  tasks = Array(RemoteRef, 0)
  for zBlock in 0:(imageDepth / imageDz - 1)
    startImage = endImage
    endImage = startImage + imageDz
    info("StartImage = ", startImage)
    info("endImage = ", endImage)

    task = @spawn imageConvertionProcess(sliceDirectory, outputDirectory,
                            beginImageStack, startImage, endImage,
```

```
                            imageDx, imageDy, imageDz,
                            imageHeight, imageWidth,
                            centroidsCalc, boundaryMat)
    push!(tasks, task)
  end

  # Waiting for processes completion
  for task in tasks
    wait(task)
  end

  info("Merging obj models")
  Model2Obj.mergeObj(string(outputDirectory,"MODELS"))

end

function imageConvertionProcess(sliceDirectory, outputDirectory,
                                beginImageStack, startImage, endImage,
                                imageDx, imageDy, imageDz,
                                imageHeight, imageWidth,
                                centroids, boundaryMat)
  """
  Support function for converting a stack of image on a single
  independent process
  """

  info("Transforming png data into 3d array")
  theImage = PngStack2Array3dJulia.pngstack2array3d(sliceDirectory, startImage, endImage, centi

  centroidsSorted = sort(vec(reshape(centroids, 1, 2)))
  foreground = centroidsSorted[2]
  background = centroidsSorted[1]
  debug(string("background = ", background, " foreground = ", foreground))
  for xBlock in 0:(imageHeight / imageDx - 1)
    for yBlock in 0:(imageWidth / imageDy - 1)
      yStart = xBlock * imageDx
      xStart = yBlock * imageDy
      #xEnd = xStart + imageDx
      #yEnd = yStart + imageDy
      xEnd = xStart + imageDy
      yEnd = yStart + imageDx
      debug("***********")
      debug(string("xStart = ", xStart, " xEnd = ", xEnd))
      debug(string("yStart = ", yStart, " yEnd = ", yEnd))
      debug("theImage dimensions: ", size(theImage)[1], " ", size(theImage[1])[1], " ", size(tl
```

```
      # Getting a slice of theImage array

      image = Array(Uint8, (convert(Int, length(theImage)), convert(Int, xEnd - xStart), conve
      for z in 1:length(theImage)
        for x in 1 : (xEnd - xStart)
          for y in 1 : (yEnd - yStart)
            image[z, x, y] = theImage[z][x + xStart, y + yStart]
          end
        end
      end

      nx, ny, nz = size(image)
      chains3D = Array(Uint8, 0)
      zStart = startImage - beginImageStack
      for y in 0:(nx - 1)
        for x in 0:(ny - 1)
          for z in 0:(nz - 1)
            if(image[z + 1, x + 1, y + 1] == foreground)
              push!(chains3D, y + ny * (x + nx * z))
            end
          end
        end
      end

      if(length(chains3D) != 0)
        # Computing boundary chain
        debug("chains3d = ", chains3D)
        debug("Computing boundary chain")
        objectBoundaryChain = Lar2Julia.larBoundaryChain(boundaryMat, chains3D)
        debug("Converting models into obj")
        try
          mkdir(string(outputDirectory, "MODELS"))
        catch
        end
        # IMPORTANT: inverting xStart and yStart for obtaining correct rotation of the model
        outputFilename = string(outputDirectory, "MODELS/model-", xBlock, "-", yBlock, "_outpu
        Model2Obj.writeToObj(imageDx, imageDy, imageDz, yStart, xStart, zStart, objectBoundary
      else
        debug("Model is empty")
      end
    end
  end
end

function getBorderMatrix(borderFilename)
  """
```

```
    TO REMOVE WHEN PORTING OF LARCC IN JULIA IS COMPLETED

    Get the border matrix from json file and convert it in
    CSC format
    """
    # Loading borderMatrix from json file
    borderData = JSON.parsefile(borderFilename)
    row = Array(Int64, length(borderData["ROW"]))
    col = Array(Int64, length(borderData["COL"]))
    data = Array(Int64, length(borderData["DATA"]))

    for i in 1: length(borderData["ROW"])
      row[i] = borderData["ROW"][i]
    end

    for i in 1: length(borderData["COL"])
      col[i] = borderData["COL"][i]
    end

    for i in 1: length(borderData["DATA"])
      data[i] = borderData["DATA"][i]
    end

    # Converting csr matrix to csc
    csrBorderMatrix = Pysparse.csr_matrix((data,col,row), shape=(borderData["ROWCOUNT"],borderDa
    denseMatrix = pycall(csrBorderMatrix["toarray"],PyAny)

    cscBoundaryMat = sparse(denseMatrix)

    return cscBoundaryMat

  end
  end
  ◇
```

"src/generateBorderMatrix.jl" 9≡

```
  module GenerateBorderMatrix
  """
  Module for generation of the boundary matrix
  """

  type MatrixObject
    ROWCOUNT
```

```
  COLCOUNT
  ROW
  COL
  DATA
end


export computeOriented3Border, writeBorder, getOriented3BorderPath

require(string(Pkg.dir("ImagesToLARModel/src"), "/larUtils.jl"))

import LARUtils
using PyCall

import JSON

@pyimport sys
unshift!(PyVector(pyimport("sys")["path"]), "") # Search for python modules in folder
# Search for python modules in package folder
unshift!(PyVector(pyimport("sys")["path"]), Pkg.dir("ImagesToLARModel/src"))
@pyimport larcc # Importing larcc from local folder

# Compute the 3-border operator
function computeOriented3Border(nx, ny, nz)
  """
  Compute the 3-border matrix using a modified
  version of larcc
  """
  V, bases = LARUtils.getBases(nx, ny, nz)
  boundaryMat = larcc.signedCellularBoundary(V, bases)
  return boundaryMat

end

function writeBorder(boundaryMatrix, outputFile)
  """
  Write 3-border matrix on json file

  boundaryMatrix: matrix to write on file
  outputFile: path of the outputFile
  """

  rowcount = boundaryMatrix[:shape][1]
  colcount = boundaryMatrix[:shape][2]

  row = boundaryMatrix[:indptr]
```

```
    col = boundaryMatrix[:indices]
    data = boundaryMatrix[:data]

    # Writing informations on file
    outfile = open(outputFile, "w")

    matrixObj = MatrixObject(rowcount, colcount, row, col, data)
    JSON.print(outfile, matrixObj)
    close(outfile)

  end

  function getOriented3BorderPath(borderPath, nx, ny, nz)
    """
    Try reading 3-border matrix from file. If it fails matrix
    is computed and saved on disk in JSON format

    borderPath: path of border directory
    nx, ny, nz: image dimensions
    """

    filename = string(borderPath,"/border_", nx, "-", ny, "-", nz, ".json")
    if !isfile(filename)
      border = computeOriented3Border(nx, ny, nz)
      writeBorder(border, filename)
    end
    return filename

  end
  end
  ◇
```

"src/lar2Julia.jl" 11≡

```
  module Lar2Julia
  """
  larcc functions for Julia
  """
  export larBoundaryChain, cscChainToCellList

  import JSON

  using Logging
```

```
function larBoundaryChain(cscBoundaryMat, brcCellList)
  """
  Compute boundary chains
  """

  # Computing boundary chains
  n = size(cscBoundaryMat)[1]
  m = size(cscBoundaryMat)[2]

  debug("Boundary matrix size: ", n, "\t", m)

  data = ones(Int64, length(brcCellList))

  i = Array(Int64, length(brcCellList))
  for k in 1:length(brcCellList)
    i[k] = brcCellList[k] + 1
  end

  j = ones(Int64, length(brcCellList))

  debug("cscChain rows length: ", length(i))
  debug("cscChain columns length: ", length(j))
  debug("cscChain data length: ", length(brcCellList))

  debug("rows ", i)
  debug("columns ", j)
  debug("data ", data)

  cscChain = sparse(i, j, data, m, 1)
  cscmat = cscBoundaryMat * cscChain
  out = cscBinFilter(cscmat)
  return out
end

function cscBinFilter(CSCm)
  k = 1
  data = nonzeros(CSCm)
  sgArray = copysign(1, data)

  while k <= nnz(CSCm)
    if data[k] % 2 == 1 || data[k] % 2 == -1
      data[k] = 1 * sgArray[k]
    else
      data[k] = 0
    end
    k += 1
```

```
  end

  return CSCm
end

function cscChainToCellList(CSCm)
  """
  Get a csc containing a chain and returns
  the cell list of the "+1" oriented faces
  """
  data = nonzeros(CSCm)
  # Now I need to remove zero element (problem with Julia nonzeros)
  nonzeroData = Array(Int64, 0)
  for n in data
    if n != 0
      push!(nonzeroData, n)
    end
  end

  cellList = Array(Int64,0)
  for (k, theRow) in enumerate(findn(CSCm)[1])
    if nonzeroData[k] == 1
      push!(cellList, theRow)
    end
  end
  return cellList
end
end
◇
```

"src/larUtils.jl" 13≡

```
module LARUtils
"""
Utility functions for extracting 3d models from images
"""
export ind, invertIndex, getBases

function ind(x, y, z, nx, ny)
    """
    Transform coordinates into linearized matrix indexes
    """
    return x + (nx+1) * (y + (ny+1) * (z))
  end
```

```
function invertIndex(nx,ny,nz)
  """
  Invert indexes
  """
  nx, ny, nz = nx + 1, ny + 1, nz + 1
  function invertIndex0(offset)
      a0, b0 = trunc(offset / nx), offset % nx
      a1, b1 = trunc(a0 / ny), a0 % ny
      a2, b2 = trunc(a1 / nz), a1 % nz
      return b0, b1, b2
  end
  return invertIndex0
end


function getBases(nx, ny, nz)
  """
  Compute all LAR relations
  """

  function the3Dcell(coords)
    x,y,z = coords
    return [ind(x,y,z,nx,ny),ind(x+1,y,z,nx,ny),ind(x,y+1,z,nx,ny),ind(x,y,z+1,nx,ny),ind(x+1,y
            ind(x+1,y,z+1,nx,ny),ind(x,y+1,z+1,nx,ny),ind(x+1,y+1,z+1,nx,ny)]
  end

  # Calculating vertex coordinates (nx * ny * nz)
  V = Array{Int64}[]
  for z in 0:nz
    for y in 0:ny
      for x in 0:nx
        push!(V,[x,y,z])
      end
    end
  end


  # Building CV relationship
  CV = Array{Int64}[]
  for z in 0:nz-1
    for y in 0:ny-1
      for x in 0:nx-1
        push!(CV,the3Dcell([x,y,z]))
      end
```

```
    end
  end

  # Building FV relationship
  FV = Array{Int64}[]
  v2coords = invertIndex(nx,ny,nz)

  for h in 0:(length(V)-1)
    x,y,z = v2coords(h)

    if (x < nx) && (y < ny)
      push!(FV, [h,ind(x+1,y,z,nx,ny),ind(x,y+1,z,nx,ny),ind(x+1,y+1,z,nx,ny)])
    end

    if (x < nx) && (z < nz)
      push!(FV, [h,ind(x+1,y,z,nx,ny),ind(x,y,z+1,nx,ny),ind(x+1,y,z+1,nx,ny)])
    end

    if (y < ny) && (z < nz)
      push!(FV,[h,ind(x,y+1,z,nx,ny),ind(x,y,z+1,nx,ny),ind(x,y+1,z+1,nx,ny)])
    end

  end

  # Building VV relationship
  VV = map((x)->[x], 0:length(V)-1)

  # Building EV relationship
  EV = Array{Int64}[]
  for h in 0:length(V)-1
    x,y,z = v2coords(h)
    if (x < nx)
      push!(EV, [h,ind(x+1,y,z,nx,ny)])
    end
    if (y < ny)
      push!(EV, [h,ind(x,y+1,z,nx,ny)])
    end
    if (z < nz)
      push!(EV, [h,ind(x,y,z+1,nx,ny)])
    end
  end

  # return all basis
  return V, (VV, EV, FV, CV)
end
end
```

◇

"src/model2Obj.jl" 16≡

```
module Model2Obj
"""
Module that takes a 3d model and write it on
obj files
"""

require(string(Pkg.dir("ImagesToLARModel/src"), "/larUtils.jl"))

import LARUtils

using Logging

export writeToObj, mergeObj

function writeToObj(imageDx, imageDy, imageDz,
                    xStart, yStart, zStart,
                    objectBoundaryChain, outputFilename)
  """
  Takes the boundary chain of a part of the model
  and writes it on stl files
  """
  V, bases = LARUtils.getBases(imageDx, imageDy, imageDz)
  FV = bases[3]

  outputVtx = string(outputFilename, "_vtx.stl")
  outputFaces = string(outputFilename, "_faces.stl")

  fileVertex = open(outputVtx, "w")
  fileFaces = open(outputFaces, "w")

  vertex_count = 1
  count = 0

  #b2cells = Lar2Julia.cscChainToCellList(objectBoundaryChain)
  # Get all cells (independently from orientation)
  b2cells = findn(objectBoundaryChain)[1]

  debug("b2cells = ", b2cells)

  for f in b2cells
```

```
    old_vertex_count = vertex_count
    for vtx in FV[f]
      write(fileVertex, "v ")
      write(fileVertex, string(convert(Int64, V[vtx + 1][1] + xStart)))
      write(fileVertex, " ")
      write(fileVertex, string(convert(Int64, V[vtx + 1][2] + yStart)))
      write(fileVertex, " ")
      write(fileVertex, string(convert(Int64, V[vtx + 1][3] + zStart)))
      write(fileVertex, "\n")
      vertex_count += 1
    end

    write(fileFaces, "f ")
    write(fileFaces, string(old_vertex_count))
    write(fileFaces, " ")
    write(fileFaces, string(old_vertex_count + 1))
    write(fileFaces, " ")
    write(fileFaces, string(old_vertex_count + 3))
    write(fileFaces, "\n")

    write(fileFaces, "f ")
    write(fileFaces, string(old_vertex_count))
    write(fileFaces, " ")
    write(fileFaces, string(old_vertex_count + 3))
    write(fileFaces, " ")
    write(fileFaces, string(old_vertex_count + 2))
    write(fileFaces, "\n")

  end

  close(fileVertex)
  close(fileFaces)

end

function mergeObj(modelDirectory)
  """
  Merge stl files in a single obj file

  modelDirectory: directory containing models
  """

  files = readdir(modelDirectory)
  vertices_files = files[find(s -> contains(s,string("_vtx.stl")), files)]
  faces_files = files[find(s -> contains(s,string("_faces.stl")), files)]
  obj_file = open(string(modelDirectory,"/","model.obj"),"w") # Output file
```

```
vertices_counts = Array(Int64, length(vertices_files))
number_of_vertices = 0
for i in 1:length(vertices_files)
  vtx_file = vertices_files[i]
  f = open(string(modelDirectory, "/", vtx_file))

  # Writing vertices on the obj file
  for ln in eachline(f)
    write(obj_file, ln)
    number_of_vertices += 1
  end
  # Saving number of vertices
  vertices_counts[i] = number_of_vertices
  close(f)
end

for i in 1 : length(faces_files)
  faces_file = faces_files[i]
  f = open(string(modelDirectory, "/", faces_file))

  for ln in eachline(f)
    splitted = split(ln)
    write(obj_file, "f ")
    if i > 1
      write(obj_file, string(parse(splitted[2]) + vertices_counts[i - 1], " "))
      write(obj_file, string(parse(splitted[3]) + vertices_counts[i - 1], " "))
      write(obj_file, string(parse(splitted[4]) + vertices_counts[i - 1]))
    else
      write(obj_file, string(splitted[2], " "))
      write(obj_file, string(splitted[3], " "))
      write(obj_file, splitted[4])
    end
    write(obj_file, "\n")
  end
  close(f)
end
close(obj_file)

# Removing all tmp files
for vtx_file in vertices_files
  rm(string(modelDirectory, "/", vtx_file))
end

for fcs_file in faces_files
  rm(string(modelDirectory, "/", fcs_file))
```

```
    end

  end
  end
  ◇
```

"src/pngStack2Array3dJulia.jl" 19≡

```
  module PngStack2Array3dJulia

  """
  This module loads a stack of png files returning
  an array of pixel values divided into segments
  """

  export calculateClusterCentroids, pngstack2array3d, getImageData, convertImages

  using Images # For loading png images
  using Colors # For grayscale images
  using PyCall # For including python clustering
  using Logging
  @pyimport scipy.ndimage as ndimage
  @pyimport scipy.cluster.vq as cluster

  NOISE_SHAPE_DETECT=10

  function getImageData(imageFile)
    """
    Get width and heigth from a png image
    """

    input = open(imageFile, "r")
    data = readbytes(input, 24)

    if (data[2:4] != [80, 78, 71] && data[13:16] != [73, 72, 68, 82])
      error("This is not a png image")
    end

    w = data[17:20]
    h = data[21:24]

    width = reinterpret(Int32, reverse(w))[1]
    height = reinterpret(Int32, reverse(h))[1]
```

```
  close(input)

  return width, height
end

function calculateClusterCentroids(path, image, numberOfClusters = 2)
  """
  Loads an image and calculate cluster centroids for segmentation

  path: Path of the image folder
  image: name of the image
  numberOfClusters: number of desidered clusters
  """
  imageFilename = string(path, image)

  img = imread(imageFilename) # Open png image with Julia Package

  rgb_img = convert(Image{ColorTypes.RGB}, img)
  gray_img = convert(Image{ColorTypes.Gray}, rgb_img)
  imArray = raw(gray_img)

  imageWidth = size(imArray)[1]
  imageHeight = size(imArray)[2]

  # Getting pixel values and saving them with another shape
  image3d = Array(Array{Uint8,2}, 0)

  # Inserting page on another list and reshaping
  push!(image3d, imArray)
  pixel = reshape(image3d[1], (imageWidth * imageHeight), 1)

  # Segmenting image using kmeans
  # https://en.wikipedia.org/wiki/Image_segmentation#Clustering_methods

  centroids,_ = cluster.kmeans(pixel, numberOfClusters)

  return centroids

end


function pngstack2array3d(path, minSlice, maxSlice, centroids)
  """
  Import a stack of PNG images into a 3d array

  path: path of images directory
```

```
minSlice and maxSlice: number of first and last slice
centroids: centroids for image segmentation
"""

# image3d contains all images values
image3d = Array(Array{Uint8,2}, 0)

debug("maxSlice = ", maxSlice, " minSlice = ", minSlice)
files = readdir(path)

for slice in minSlice : (maxSlice - 1)
  debug("slice = ", slice)
  imageFilename = string(path, files[slice + 1])
  debug("image name: ", imageFilename)
  img = imread(imageFilename) # Open png image with Julia Package

  # Converting image in grayscale
  rgb_img = convert(Image{ColorTypes.RGB}, img)
  gray_img = convert(Image{ColorTypes.Gray}, rgb_img)
  imArray = raw(gray_img) # Putting pixel values into RAW 3d array
  debug("imArray size: ", size(imArray))

  # Inserting page on another list and reshaping
  push!(image3d, imArray)

end

# Removing noise using a median filter and quantization
for page in 1:length(image3d)

  # Denoising
  image3d[page] = ndimage.median_filter(image3d[page], NOISE_SHAPE_DETECT)

  # Image Quantization
  debug("page = ", page)
  debug("image3d[page] dimensions: ", size(image3d[page])[1], "\t", size(image3d[page])[2])
  pixel = reshape(image3d[page], size(image3d[page])[1] * size(image3d[page])[2] , 1)
  qnt,_ = cluster.vq(pixel,centroids)

  # Reshaping quantization result
  centers_idx = reshape(qnt, size(image3d[page],1), size(image3d[page],2))
  #centers_idx = reshape(qnt, size(image3d[page]))

  # Inserting quantized values into 3d image array
  tmp = Array(Uint8, size(image3d[page],1), size(image3d[page],2))
```

```
    for j in 1:size(image3d[1],2)
      for i in 1:size(image3d[1],1)
        tmp[i,j] = centroids[centers_idx[i,j] + 1]
      end
    end

    image3d[page] = tmp

  end

  return image3d
end

function convertImages(inputPath, outputPath, bestImage)
  """
  Get all images contained in inputPath directory
  saving them in outputPath directory in png format.
  If images have one of two odd dimensions, they will be resized
  and if folder contains an odd number of images another one will be
  added

  inputPath: Directory containing input images
  outputPath: Temporary directory containing png images
  bestImage: Image chosen for centroids computation

  Returns the new name for the best image
  """

  imageFiles = readdir(inputPath)
  numberOfImages = length(imageFiles)
  outputPrefix = ""
  for i in 1: length(string(numberOfImages)) - 1
    outputPrefix = string(outputPrefix,"0")
  end

  newBestImage = ""
  imageNumber = 0
  for imageFile in imageFiles
    img = imread(string(inputPath, imageFile))

    # resizing images if they do not have even dimensions
    dim = size(img)
    if(dim[1] % 2 != 0)
      debug("Image has odd x; resizing")
      xrange = 1: dim[1] - 1
    else
```

```
      xrange = 1: dim[1]
    end

    if(dim[2] % 2 != 0)
      debug("Image has odd y; resizing")
      yrange = 1: dim[2] - 1
    else
      yrange = 1: dim[2]
    end

    img = subim(img, xrange, yrange)

    outputFilename = string(outputPath, outputPrefix[length(string(imageNumber)):end], imageNu
    imwrite(img, outputFilename)

    # Searching the best image
    if(imageFile == bestImage)
      newBestImage = string(outputPrefix[length(string(imageNumber)):end], imageNumber,".png")
    end

    imageNumber += 1
  end

  # Adding another image if they are odd
  if(numberOfImages % 2 != 0)
    debug("Odd images, adding one")
    bestImage = imread(string(outputPath, "/", newBestImage))
    imArray = zeros(Uint8, size(bestImage))
    img = grayim(imArray)
    outputFilename = string(outputPath, "/", outputPrefix[length(string(imageNumber)):end], ima
    imwrite(img, outputFilename)
  end

  return newBestImage
end

end
◇
```

2.1 Installing the library

3 Conclusions

3.1 Results

3.2 Further improvements

References

[CL13] CVD-Lab, *Linear algebraic representation*, Tech. Report 13-00, Roma Tre University, October 2013.

A Utility functions

B Tests

Generation of the border matrix

```
"test/generateBorderMatrix.jl" 24≡
     push!(LOAD_PATH, "../../")
     import GenerateBorderMatrix
     import JSON
     using Base.Test

     function testComputeOriented3Border()
       """
       Test function for computeOriented3Border
       """
       boundaryMatrix = GenerateBorderMatrix.computeOriented3Border(2,2,2)

       rowcount = boundaryMatrix[:shape][1]
       @test rowcount == 36
       colcount = boundaryMatrix[:shape][2]
       @test colcount == 8
       row = boundaryMatrix[:indptr]
       @test row == [0,1,2,3,4,5,7,8,9,11,12,13,15,17,18,19,20,22,23,24,26,27,29,30,32,34,35,37,39,4
       col = boundaryMatrix[:indices]
       @test col == [0,0,0,1,1,0,1,1,2,0,2,2,3,1,3,2,3,3,2,3,0,4,4,4,1,5,5,4,5,5,2,6,4,6,6,3,7,5,7,6
       data = boundaryMatrix[:data]
       @test data == [-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

     end

     function testWriteBorder()
```

```
    """
    Test for writeBorder
    """
    boundaryMatrix = GenerateBorderMatrix.computeOriented3Border(2,2,2)
    filename = "borderFile"

    GenerateBorderMatrix.writeBorder(boundaryMatrix, filename)
    @test isfile(filename)

    # Loading borderMatrix from json file
    borderData = JSON.parsefile(filename)
    row = Array(Int64, length(borderData["ROW"]))
    col = Array(Int64, length(borderData["COL"]))
    data = Array(Int64, length(borderData["DATA"]))

    @test borderData["ROW"] == [0,1,2,3,4,5,7,8,9,11,12,13,15,17,18,19,20,22,23,24,26,27,29,30,3
    @test borderData["COL"] == [0,0,0,1,1,0,1,1,2,0,2,2,3,1,3,2,3,3,2,3,0,4,4,4,1,5,5,4,5,5,2,6,
    @test borderData["DATA"] == [-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

    rm(filename)

  end

  function executeAllTests()
    @time testComputeOriented3Border()
    @time testWriteBorder()
    println("Tests completed.")
  end

  executeAllTests()
```

◇

Conversion of a png stack to a 3D array

"test/pngStack2Array3dJulia.jl" 25≡

```
  push!(LOAD_PATH, "../../")
  import PngStack2Array3dJulia
  using Base.Test

  function testGetImageData()
    """
    Test function for getImageData
```

```
  """

  width, height = PngStack2Array3dJulia.getImageData("images/0.png")

  @test width == 50
  @test height == 50

end

function testCalculateClusterCentroids()
  """
  Test function for calculateClusterCentroids
  """
  path = "images/"
  image = 0
  centroids = PngStack2Array3dJulia.calculateClusterCentroids(path, image, 2)

  expected = [0, 253]
  centroids = vec(reshape(centroids, 1, 2))

  @test sort(centroids) == expected
end

function testPngstack2array3d()
  """
  Test function for pngstack2array3d
  """
  path = "images/"
  minSlice = 0
  maxSlice = 4
  centroids = PngStack2Array3dJulia.calculateClusterCentroids(path, 0, 2)
  image3d = PngStack2Array3dJulia.pngstack2array3d(path, minSlice, maxSlice, centroids)

  @test size(image3d)[1] == 5
  @test size(image3d[1])[1] == 50
  @test size(image3d[1])[2] == 200

end

function executeAllTests()
  @time testCalculateClusterCentroids()
  @time testPngstack2array3d()
  @time testGetImageData()
  println("Tests completed.")
end
```

```
executeAllTests()

◇
```

Test for LAR utilities

"test/LARUtils.jl" 27≡

```
push!(LOAD_PATH, "../../")
import LARUtils
using Base.Test

function testInd()
  """
  Test function for ind
  """

  nx = 2
  ny = 2

  @test LARUtils.ind(0, 0, 0, nx, ny) == 0
  @test LARUtils.ind(1, 1, 1, nx, ny) == 13
  @test LARUtils.ind(2, 5, 4, nx, ny) == 53
  @test LARUtils.ind(1, 1, 1, nx, ny) == 13
  @test LARUtils.ind(2, 7, 1, nx, ny) == 32
  @test LARUtils.ind(1, 0, 3, nx, ny) == 28
end

function executeAllTests()
  @time testInd()
  println("Tests completed.")
end

executeAllTests()

◇
```