

# 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 [\[CL13\]](#))

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# 1 Introduction

## 2 Exporting the library

```
"src/ImagesToLARModel.jl" 3≡
module ImagesToLARModel
"""
Main module for the library. It starts conversion
taking configuration parameters
"""
require(string(Pkg.dir("ImagesToLARModel/src"), "/imagesConversion.jl"))

import JSON
import ImagesConversion

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]

try
    if configuration["parallelMerge"] == "true"
        parallelMerge = true
    else
        parallelMerge = false
    end
catch
    parallelMerge = false
end

return configuration["inputDirectory"], configuration["outputDirectory"], configuration["bestEffort"],
    configuration["nx"], configuration["ny"], configuration["nz"],
    DEBUG_LEVELS[configuration["DEBUG_LEVEL"]]
end
```

```

function convertImagesToLARModel(configurationFile)
    """
    Start conversion 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, parallelMerge = false)
    """
    Start conversion 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)
    ImagesConversion.images2LARModel(nx, ny, nz, bestImage, inputDirectory, outputDirectory, par
end
end
◇

```

```

"src/imagesConversion.jl" 4≡
module ImagesConversion

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

import GenerateBorderMatrix
import PngStack2Array3dJulia
import Lar2Julia
import Model2Obj
import LARUtils

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, parallelMerge)
    """
    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, newBestImage))

```

```

imageDepth = length(readdir(tempDirectory))

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

# Starting images conversion and border computation
info("Starting images conversion")
startImageConversion(tempDirectory, newBestImage, outputDirectory, borderFilename,
                      imageHeight, imageWidth, imageDepth,
                      nx, ny, nz,
                      numberOfClusters, parallelMerge)

end

function startImageConversion(sliceDirectory, bestImage, outputDirectory, borderFilename,
                              imageHeight, imageWidth, imageDepth,
                              imageDx, imageDy, imageDz,
                              numberOfClusters, parallelMerge)

    """
    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, n
    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 imageConversionProcess(sliceDirectory, outputDirectory,
                                         beginImageStack, startImage, endImage,
                                         imageDx, imageDy, imageDz,
                                         imageHeight, imageWidth,
                                         centroidsCalc, boundaryMat)

    push!(tasks, task)
    =#
    imageConversionProcess(sliceDirectory, outputDirectory,
                           beginImageStack, startImage, endImage,
                           imageDx, imageDy, imageDz,
                           imageHeight, imageWidth,
                           centroidsCalc, boundaryMat)

end

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

info("Merging boundaries")
# Merge Boundaries files
Model2Obj.mergeBoundaries(string(outputDirectory, "MODELS"),
                           imageHeight, imageWidth, imageDepth,
                           imageDx, imageDy, imageDz)

info("Merging obj models")
if parallelMerge
    Model2Obj.mergeObjParallel(string(outputDirectory, "MODELS"))
else
    Model2Obj.mergeObj(string(outputDirectory, "MODELS"))
end

end

function imageConversionProcess(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, centroids)

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(theImage[1][1]))

        # Getting a slice of theImage array

        image = Array{UInt8, 3}(convert{Int, UInt8}(length(theImage)), convert{Int, UInt8}(xEnd - xStart), convert{Int, UInt8}(yEnd - yStart))
        debug("image size: ", size(image))
        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, 3}(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
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
    models = LARUtils.computeModelAndBoundaries(imageDx, imageDy, imageDz, yStart, xStart,

    V, FV = models[1][1] # inside model
    V_left, FV_left = models[2][1]
    V_right, FV_right = models[3][1] # right boundary
    V_top, FV_top = models[4][1] # top boundary
    V_bottom, FV_bottom = models[5][1] # bottom boundary
    V_front, FV_front = models[6][1] # front boundary
    V_back, FV_back = models[7][1] # back boundary

    # Writing all models on disk
    model_outputFilename = string(outputDirectory, "MODELS/model_output_", xBlock, "-", yBlock, ".obj")
    Model2Obj.writeToObj(V, FV, model_outputFilename)

    left_outputFilename = string(outputDirectory, "MODELS/left_output_", xBlock, "-", yBlock, ".obj")
    Model2Obj.writeToObj(V_left, FV_left, left_outputFilename)

    right_outputFilename = string(outputDirectory, "MODELS/right_output_", xBlock, "-", yBlock, ".obj")
    Model2Obj.writeToObj(V_right, FV_right, right_outputFilename)

    top_outputFilename = string(outputDirectory, "MODELS/top_output_", xBlock, "-", yBlock, ".obj")
    Model2Obj.writeToObj(V_top, FV_top, top_outputFilename)

    bottom_outputFilename = string(outputDirectory, "MODELS/bottom_output_", xBlock, "-", yBlock, ".obj")
    Model2Obj.writeToObj(V_bottom, FV_bottom, bottom_outputFilename)

```

```

        front_outputFilename = string(outputDirectory, "MODELS/front_output_", xBlock, "-", yBlock)
        Model2Obj.writeToObj(V_front, FV_front, front_outputFilename)

        back_outputFilename = string(outputDirectory, "MODELS/back_output_", xBlock, "-", yBlock)
        Model2Obj.writeToObj(V_back, FV_back, back_outputFilename)
    else
        debug("Model is empty")
    end
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, 1}(length(borderData["ROW"]))
    col = Array{Int64, 1}(length(borderData["COL"]))
    data = Array{Int64, 1}(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"],borderData["COLCOUNT"]))
    denseMatrix = pycall(csrBorderMatrix["toarray"],PyAny)

    cscBoundaryMat = sparse(denseMatrix)

    return cscBoundaryMat
end

```

```

end
◇

"src/generateBorderMatrix.jl" 11≡
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" 13≡
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" 14≡
module LARUtils

```

```

"""
Utility functions for extracting 3d models from images
"""

using Logging

export ind, invertIndex, getBases, removeDoubleVerticesAndFaces, computeModel, computeModelAnd

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,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
end

```



```

        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
end

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

function lessThanVertices(v1, v2)
    """
    Utility function for comparing vertices coordinates
    """

    if v1[1] == v2[1]
        if v1[2] == v2[2]
            return v1[3] < v2[3]
        end
        return v1[2] < v2[2]
    end
    return v1[1] < v2[1]
end

function removeDoubleVerticesAndFaces(V, FV, facesOffset)
    """
    Removes double vertices and faces from a LAR model

    V: Array containing all vertices
    FV: Array containing all faces
    facesOffset: offset for faces indices
    """

    newV, indices = removeDoubleVertices(V)
    reindexedFaces = reindexVerticesInFaces(FV, indices, facesOffset)
    newFV = unique(FV)

    return newV, newFV
end

function removeDoubleVertices(V)
    """

```

```

Remove double vertices from a LAR model

V: Array containing all vertices of the model
"""

# Sort the vertices list and returns the ordered indices
orderedIndices = sortperm(V, lt = lessThanVertices, alg=MergeSort)

orderedVerticesAndIndices = collect(zip(sort(V, lt = lessThanVertices),
                                         orderedIndices))

newVertices = Array{Array{Int}, 0}()
indices = zeros{Int, length(V)}
prevv = Nothing
i = 1
for (v, ind) in orderedVerticesAndIndices
    if v == prevv
        indices[ind] = i - 1
    else
        push!(newVertices, v)
        indices[ind] = i
        i += 1
        prevv = v
    end
end
return newVertices, indices
end

function reindexVerticesInFaces(FV, indices, offset)
    """
    Reindex vertices indexes in faces array

    FV: Faces array of the LAR model
    indices: new Indices for faces
    offset: offset for faces indices
    """

    for f in FV
        for i in 1: length(f)
            f[i] = indices[f[i] - offset] + offset
        end
    end
    return FV
end

function removeVerticesAndFacesFromBoundaries(V, FV)
    """

```

```

Remove vertices and faces duplicates on
boundaries models

V,FV: lar model of two merged boundaries
"""

# Removing double faces and vertices
newV, indices = removeDoubleVertices(V)
uniqueIndices = unique(indices)
toRemove = Array(Int,0)

for i in uniqueIndices
    if(count((x) -> x == i, indices) > 1)
        push!(toRemove, i)
    end
end

V_final = Array{Array{Int}, 0}
FV_final = Array{Array{Int}, 0}

# Removing all common vertices
for i in 1: length(newV)
    if !(i in toRemove)
        push!(V_final, newV[i])
    end
end

# Creating an array of faces with explicit vertices
FV_vertices = Array{Array{Array{Int}}, length(FV)}
for i in 1 : length(FV)
    FV_vertices[i] = Array{Array{Int}, 0}
    for vtx in FV[i]
        push!(FV_vertices[i], V[vtx])
    end
end

# Computing the final model with the remaining vertices
for face in FV_vertices
    remove = false
    tmp = Array{Int, 0}
    for vtx in face
        ind = findfirst(V_final, vtx)
        if (ind == 0)
            remove = true
        else
            push!(tmp, ind)
        end
    end
end

```

```

        end
    end
    if (remove == false)
        push!(FV_final, tmp)
    end
end

return V_final, FV_final
end

function computeModel(imageDx, imageDy, imageDz,
                      xStart, yStart, zStart,
                      facesOffset, objectBoundaryChain)
    """
    Takes the boundary chain of a part of the entire model
    and returns a LAR model

    imageDx, imageDy, imageDz: Boundary dimensions
    xStart, yStart, zStart: Offset of this part of the model
    facesOffset: Offset for the faces
    objectBoundaryChain: Sparse csc matrix containing the cells
    """

    V, bases = getBases(imageDx, imageDy, imageDz)
    FV = bases[3]

    V_model = Array{Array{Int}, 0}
    FV_model = Array{Array{Int}, 0}

    vertex_count = 1

    #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]
            push!(V_model, [convert{Int}(V[vtx + 1][1] + xStart),
                            convert{Int}(V[vtx + 1][2] + yStart),
                            convert{Int}(V[vtx + 1][3] + zStart)])
            vertex_count += 1
        end
    end
end

```

```

        push!(FV_model, [old_vertex_count + facesOffset, old_vertex_count + 1 + facesOffset, old_v
        push!(FV_model, [old_vertex_count + facesOffset, old_vertex_count + 3 + facesOffset, old_v
    end

    # Removing double vertices
    return removeDoubleVerticesAndFaces(V_model, FV_model, facesOffset)

end

function isOnLeft(face, V, nx, ny, nz)
    """
    Check if face is on left boundary
    """

    for(vtx in face)
        if(V[vtx + 1][2] != 0)
            return false
        end
    end
    return true
end

function isOnRight(face, V, nx, ny, nz)
    """
    Check if face is on right boundary
    """

    for(vtx in face)
        if(V[vtx + 1][2] != ny)
            return false
        end
    end
    return true
end

function isOnTop(face, V, nx, ny, nz)
    """
    Check if face is on top boundary
    """

    for(vtx in face)
        if(V[vtx + 1][3] != nz)
            return false
        end
    end
end

```

```

    end
    return true
end

function isOnBottom(face, V, nx, ny, nz)
    ""
    Check if face is on bottom boundary
    ""

    for(vtx in face)
        if(V[vtx + 1][3] != 0)
            return false
        end
    end
    return true
end

function isOnFront(face, V, nx, ny, nz)
    ""
    Check if face is on front boundary
    ""

    for(vtx in face)
        if(V[vtx + 1][1] != nx)
            return false
        end
    end
    return true
end

function isOnBack(face, V, nx, ny, nz)
    ""
    Check if face is on back boundary
    ""

    for(vtx in face)
        if(V[vtx + 1][1] != 0)
            return false
        end
    end
    return true
end

function computeModelAndBoundaries(imageDx, imageDy, imageDz,
    xStart, yStart, zStart,
    objectBoundaryChain)

```

```

"""
Takes the boundary chain of a part of the entire model
and returns a LAR model splitting the boundaries

imageDx, imageDy, imageDz: Boundary dimensions
xStart, yStart, zStart: Offset of this part of the model
objectBoundaryChain: Sparse csc matrix containing the cells
"""

function addFaceToModel(V_base, FV_base, V, FV, face, vertex_count)
    """
    Insert a face into a LAR model

    V_base, FV_base: LAR model of the base
    V, FV: LAR model
    face: Face that will be added to the model
    vertex_count: Indices for faces vertices
    """
    new_vertex_count = vertex_count
    for vtx in FV_base[face]
        push!(V, [convert(Int, V_base[vtx + 1][1] + xStart),
                  convert(Int, V_base[vtx + 1][2] + yStart),
                  convert(Int, V_base[vtx + 1][3] + zStart)])
        new_vertex_count += 1
    end
    push!(FV, [vertex_count, vertex_count + 1, vertex_count + 3])
    push!(FV, [vertex_count, vertex_count + 3, vertex_count + 2])

    return new_vertex_count
end

V, bases = getBases(imageDx, imageDy, imageDz)
FV = bases[3]

V_model = Array{Array{Int,1},0}()
FV_model = Array{Array{Int,1},0}()

V_left = Array{Array{Int,1},0}()
FV_left = Array{Array{Int,1},0}()

V_right = Array{Array{Int,1},0}()
FV_right = Array{Array{Int,1},0}()

V_top = Array{Array{Int,1},0}()
FV_top = Array{Array{Int,1},0}()

```

```

V_bottom = Array(Array{Int},0)
FV_bottom = Array(Array{Int},0)

V_front = Array(Array{Int},0)
FV_front = Array(Array{Int},0)

V_back = Array(Array{Int},0)
FV_back = Array(Array{Int},0)

vertex_count_model = 1
vertex_count_left = 1
vertex_count_right = 1
vertex_count_top = 1
vertex_count_bottom = 1
vertex_count_front = 1
vertex_count_back = 1

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

debug("b2cells = ", b2cells)

for f in b2cells
    old_vertex_count_model = vertex_count_model
    old_vertex_count_left = vertex_count_left
    old_vertex_count_right = vertex_count_right
    old_vertex_count_top = vertex_count_top
    old_vertex_count_bottom = vertex_count_bottom
    old_vertex_count_front = vertex_count_front
    old_vertex_count_back = vertex_count_back

    # Choosing the right model for vertex
    if(isOnLeft(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_left = addFaceToModel(V, FV, V_left, FV_left, f, old_vertex_count_left)
    elseif(isOnRight(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_right = addFaceToModel(V, FV, V_right, FV_right, f, old_vertex_count_right)
    elseif(isOnTop(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_top = addFaceToModel(V, FV, V_top, FV_top, f, old_vertex_count_top)
    elseif(isOnBottom(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_bottom = addFaceToModel(V, FV, V_bottom, FV_bottom, f, old_vertex_count_bot)
    elseif(isOnFront(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_front = addFaceToModel(V, FV, V_front, FV_front, f, old_vertex_count_front)
    elseif(isOnBack(FV[f], V, imageDx, imageDy, imageDz))
        vertex_count_back = addFaceToModel(V, FV, V_back, FV_back, f, old_vertex_count_back)
    else

```



```

        vertex_count_model = addFaceToModel(V, FV, V_model, FV_model, f, old_vertex_count_model)
    end

end

# Removing double vertices
return [removeDoubleVerticesAndFaces(V_model, FV_model, 0)],
[removeDoubleVerticesAndFaces(V_left, FV_left, 0)],
[removeDoubleVerticesAndFaces(V_right, FV_right, 0)],
[removeDoubleVerticesAndFaces(V_top, FV_top, 0)],
[removeDoubleVerticesAndFaces(V_bottom, FV_bottom, 0)],
[removeDoubleVerticesAndFaces(V_front, FV_front, 0)],
[removeDoubleVerticesAndFaces(V_back, FV_back, 0)]
end
end
◇

```

```

"src/model2Obj.jl" 25≡
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, mergeObjParallel

function writeToObj(V, FV, outputFilename)
"""
Take a LAR model and write it on obj file

V: array containing vertices coordinates
FV: array containing faces
outputFilename: prefix for the output files
"""

if (length(V) != 0)

```

```

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

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

for v in V
    write(fileVertex, "v ")
    write(fileVertex, string(v[1], " "))
    write(fileVertex, string(v[2], " "))
    write(fileVertex, string(v[3], "\n"))
end

for f in FV

    write(fileFaces, "f ")
    write(fileFaces, string(f[1], " "))
    write(fileFaces, string(f[2], " "))
    write(fileFaces, string(f[3], "\n"))
end

close(fileVertex)
close(fileFaces)

end

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))
        debug("Opening ", vtx_file)
    end
end

```

```

    # 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))
    debug("Opening ", 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

function assignTasks(startInd, endInd, taskArray)
    ""

```

```

This function choose the first files to merge
creating a tree where number of processes is maximized

startInd: starting index for array subdivision
endInd: end index for array subdivision
taskArray: array containing indices of files to merge for first
""
if (endInd - startInd == 2)
    push!(taskArray, startInd)
elseif (endInd - startInd < 2)
    if (endInd % 4 != 0 && startInd != endInd)
        # Stop recursion on this branch
        push!(taskArray, startInd)
    end
    # Stop recursion doing nothing
else
    assignTasks(startInd, startInd + trunc((endInd - startInd) / 2), taskArray)
    assignTasks(startInd + trunc((endInd - startInd) / 2) + 1, endInd, taskArray)
end
end

function mergeVerticesFiles(file1, file2, startOffset)
""
Support function for merging two vertices files.
Returns the number of vertices of the merged file

file1: path of the first file
file2: path of the second file
startOffset: starting face offset for second file
""

f1 = open(file1, "a")

f2 = open(file2)
debug("Merging ", file2)
number_of_vertices = startOffset
for ln in eachline(f2)
    write(f1, ln)
    number_of_vertices += 1
end
close(f2)

close(f1)

return number_of_vertices
end

```

```

function mergeFacesFiles(file1, file2, facesOffset)
  """
  Support function for merging two faces files

  file1: path of the first file
  file2: path of the second file
  facesOffset: offset for faces
  """

  f1 = open(file1, "a")

  f2 = open(file2)
  for ln in eachline(f2)
    splitted = split(ln)
    write(f1, "f ")
    write(f1, string(parse(splitted[2]) + facesOffset, " "))
    write(f1, string(parse(splitted[3]) + facesOffset, " "))
    write(f1, string(parse(splitted[4]) + facesOffset, "\n"))
  end
  close(f2)

  close(f1)
end

function mergeObjProcesses(fileArray, facesOffset = Nothing)
  """
  Merge files on a single process

  fileArray: Array containing files that will be merged
  facesOffset (optional): if merging faces files, this array contains
    offsets for every file
  """

  if(contains(fileArray[1], string("_vtx.stl")))
    # Merging vertices files
    offsets = Array{Int, 0}
    push!(offsets, countlines(fileArray[1]))
    vertices_count = mergeVerticesFiles(fileArray[1], fileArray[2], countlines(fileArray[1]))
    rm(fileArray[2]) # Removing merged file
    push!(offsets, vertices_count)
    for i in 3: length(fileArray)
      vertices_count = mergeVerticesFiles(fileArray[1], fileArray[i], vertices_count)
      rm(fileArray[i]) # Removing merged file
      push!(offsets, vertices_count)
    end
  end
end

```

```

        end
        return offsets
    else
        # Merging faces files
        mergeFacesFiles(fileArray[1], fileArray[2], facesOffset[1])
        rm(fileArray[2]) # Removing merged file
        for i in 3 : length(fileArray)
            mergeFacesFiles(fileArray[1], fileArray[i], facesOffset[i - 1])
            rm(fileArray[i]) # Removing merged file
        end
    end
end
end

function mergeObjHelper(vertices_files, faces_files)
    """
    Support function for mergeObj. It takes vertices and faces files
    and execute a single merging step

    vertices_files: Array containing vertices files
    faces_files: Array containing faces files
    """

    numberOfImages = length(vertices_files)
    taskArray = Array{Int, 0}
    assignTasks(1, numberOfImages, taskArray)

    # Now taskArray contains first files to merge
    numberOfVertices = Array{Int, 0}
    tasks = Array{RemoteRef, 0}
    for i in 1 : length(taskArray) - 1
        task = @spawn mergeObjProcesses(vertices_files[taskArray[i] : (taskArray[i + 1] - 1)])
        push!(tasks, task)
        #append!(numberOfVertices, mergeObjProcesses(vertices_files[taskArray[i] : (taskArray[i + 1] - 1)])
    end

    # Merging last vertices files
    task = @spawn mergeObjProcesses(vertices_files[taskArray[length(taskArray)] : end])
    push!(tasks, task)
    #append!(numberOfVertices, mergeObjProcesses(vertices_files[taskArray[length(taskArray)] : end])

    for task in tasks
        append!(numberOfVertices, fetch(task))
    end

    debug("NumberOfVertices = ", numberOfVertices)
end

```

```

# Merging faces files
tasks = Array(RemoteRef, 0)
for i in 1 : length(taskArray) - 1

    task = @spawn mergeObjProcesses(faces_files[taskArray[i] : (taskArray[i + 1] - 1)],
                                    numberOfVertices[taskArray[i] : (taskArray[i + 1] - 1)])
    push!(tasks, task)

    #mergeObjProcesses(faces_files[taskArray[i] : (taskArray[i + 1] - 1)],
    #                  numberOfVertices[taskArray[i] : (taskArray[i + 1] - 1)])
end

#Merging last faces files
task = @spawn mergeObjProcesses(faces_files[taskArray[length(taskArray)] : end],
                                numberOfVertices[taskArray[length(taskArray)] : end])

push!(tasks, task)
#mergeObjProcesses(faces_files[taskArray[length(taskArray)] : end],
#                  numberOfVertices[taskArray[length(taskArray)] : end])

for task in tasks
    wait(task)
end

end

function mergeObjParallel(modelDirectory)
    """
    Merge stl files in a single obj file using a parallel
    approach. Files will be recursively merged two by two
    generating a tree where number of processes for every
    step is maximized
    Actually use of this function is discouraged. In fact
    speedup is influenced by disk speed. It could work on
    particular systems with parallel accesses on disks

    modelDirectory: directory containing models
    """

    files = readdir(modelDirectory)

    # Appending directory path to every file
    files = map((s) -> string(modelDirectory, "/", s), files)

    # While we have more than one vtx file and one faces file
    while(length(files) != 2)

```

```

vertices_files = files[find(s -> contains(s,string("_vtx.stl")), files)]
faces_files = files[find(s -> contains(s,string("_faces.stl")), files)]

# Merging files
mergeObjHelper(vertices_files, faces_files)

files = readdir(modelDirectory)
files = map((s) -> string(modelDirectory, "/", s), files)
end

mergeVerticesFiles(files[2], files[1], 0)
mv(files[2], string(modelDirectory, "/model.obj"))
rm(files[1])

end

function mergeAndRemoveDuplicates(firstPath, secondPath)
  """
  Merge two boundary files removing common faces between
  them

  firstPath, secondPath: Prefix of paths to merge
  """

  firstPathV = string(firstPath, "_vtx.stl")
  firstPathFV = string(firstPath, "_faces.stl")

  secondPathV = string(secondPath, "_vtx.stl")
  secondPathFV = string(secondPath, "_faces.stl")

  if(isfile(firstPathV) && isfile(secondPathV))

    V = Array(Array{Int}, 0)
    FV = Array(Array{Int}, 0)

    offset = 0

    # First of all open files and retrieve LAR models

    f1_V = open(firstPathV)
    f1_FV = open(firstPathFV)

    for ln in eachline(f1_V)
      splitted = split(ln)
      push!(V, [parse(splitted[2]), parse(splitted[3]), parse(splitted[4])])
      offset += 1
    end
  end
end

```



```

end

for ln in eachline(f1_FV)
    splitted = split(ln)
    push!(FV, [parse(splitted[2]), parse(splitted[3]), parse(splitted[4])])
end

close(f1_V)
close(f1_FV)

f2_V = open(secondPathV)
f2_FV = open(secondPathFV)

for ln in eachline(f2_V)
    splitted = split(ln)
    push!(V, [parse(splitted[2]), parse(splitted[3]), parse(splitted[4])])
end

for ln in eachline(f2_FV)
    splitted = split(ln)
    push!(FV, [parse(splitted[2]) + offset, parse(splitted[3]) + offset, parse(splitted[4])])
end

close(f2_V)
close(f2_FV)

V_final, FV_final = LARUtils.removeVerticesAndFacesFromBoundaries(V, FV)

# Writing model to file
rm(firstPathV)
rm(firstPathFV)
rm(secondPathV)
rm(secondPathFV)
writeToObj(V_final, FV_final, firstPath)
end
end

function mergeBoundaries(modelDirectory,
                        imageHeight, imageWidth, imageDepth,
                        imageDx, imageDy, imageDz)
    """
    Merge boundaries files. For every cell of size
    (imageDx, imageDy, imageDz) in the model grid,
    it merges right faces with next left faces, top faces
    with the next cell bottom faces, and front faces
    with the next cell back faces
    """

```

```

modelDirectory: directory containing models
imageHeight, imageWidth, imageDepth: images sizes
imageDx, imageDy, imageDz: sizes of cells grid
"""

beginImageStack = 0
endImage = beginImageStack

for zBlock in 0:(imageDepth / imageDz - 1)
    startImage = endImage
    endImage = startImage + imageDz
    for xBlock in 0:(imageHeight / imageDx - 1)
        for yBlock in 0:(imageWidth / imageDy - 1)

            # Merging right Boundary
            firstPath = string(modelDirectory, "/right_output_", xBlock, "-", yBlock, "_", startImage)
            secondPath = string(modelDirectory, "/left_output_", xBlock, "-", yBlock + 1, "_", startImage)
            mergeAndRemoveDuplicates(firstPath, secondPath)

            # Merging top boundary
            firstPath = string(modelDirectory, "/top_output_", xBlock, "-", yBlock, "_", startImage)
            secondPath = string(modelDirectory, "/bottom_output_", xBlock, "-", yBlock, "_", endImage)
            mergeAndRemoveDuplicates(firstPath, secondPath)

            # Merging front boundary
            firstPath = string(modelDirectory, "/front_output_", xBlock, "-", yBlock, "_", startImage)
            secondPath = string(modelDirectory, "/back_output_", xBlock + 1, "-", yBlock, "_", startImage)
            mergeAndRemoveDuplicates(firstPath, secondPath)

        end
    end
end
end
end
◇

```

```

"src/pngStack2Array3dJulia.jl" 34≡
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 height 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 desired 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], imageNum
    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], imageNumber, ".png")
    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" 39==
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,
    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,
    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,-1,1,1

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,-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" 41≡
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" 42≡
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()

◇

```