Novel Morphological Features for Non-mass-like Breast Lesion Classification on DCE-MRI

M. Razavi, L. Wang, T. Tan, N. Karssemeijer, L. Linsen, U. Frese, H. K. Hahn, & G. Zachmann

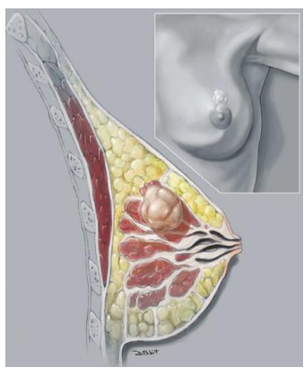
CGVR at University of Bremen (zach@cs.uni-bremen.de, mrazavi@iat.uni-bremen.de),
Fraunhofer MEVIS (horst.hahn@mevis.fraunhofer.de)

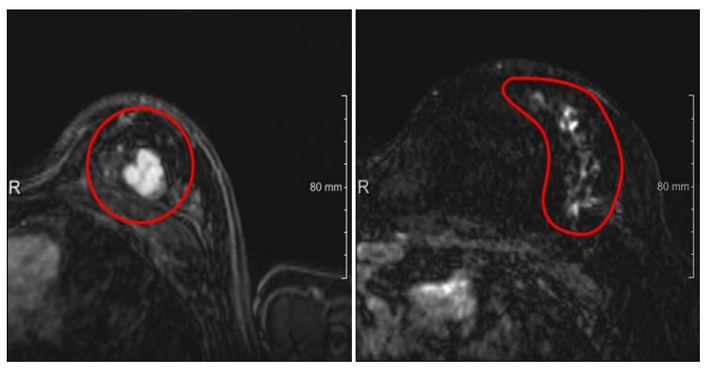
Introduction

Today breast cancer is the most common diagnosed cancer and leading cause of cancer death among women worldwide. Malignant cancer tumor, in its developed stage, can attack the surrounding cells and metastasis to distant body parts, which is the main cause of death in patients. In order to prevent that, such tumor has to be detected and treated in its early stage.

Anatomy of the Breast

Breast cancer is usually a tumor, appears from the epithelium and developing in the lactiferous ducts; it infiltrates the parenchyma (the functioning tissue of the breast other than the supporting or connective tissue).





In enhancing tissue of DC-MR image, **mass-like** tumors are clearly notable compact regions. But **Non-mass-like** enhancements have complex distribution patterns of enhancing tissue.

The processing pipeline

Input DCE-MRI →

Preprocessing
- Motion correction
- Lesion segmentation

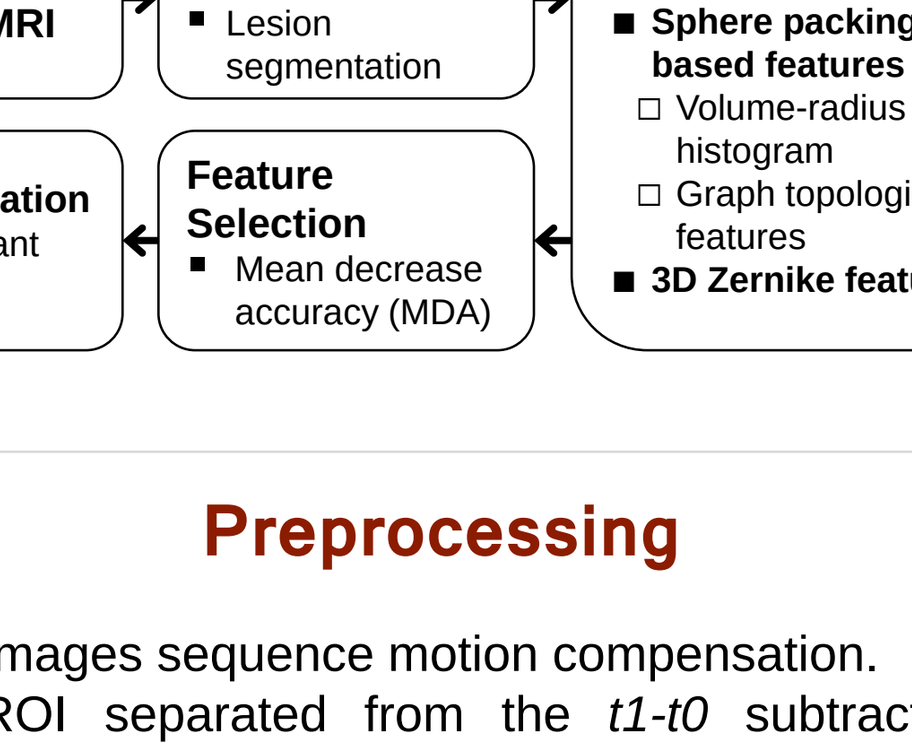
→ **Feature Extraction**
- **Sphere packing based features**
  - Volume-radius histogram
  - Graph topological features
- **3D Zernike features**

← **Feature Selection**
- Mean decrease accuracy (MDA)

← **Classification**
- Malignant
- Benign

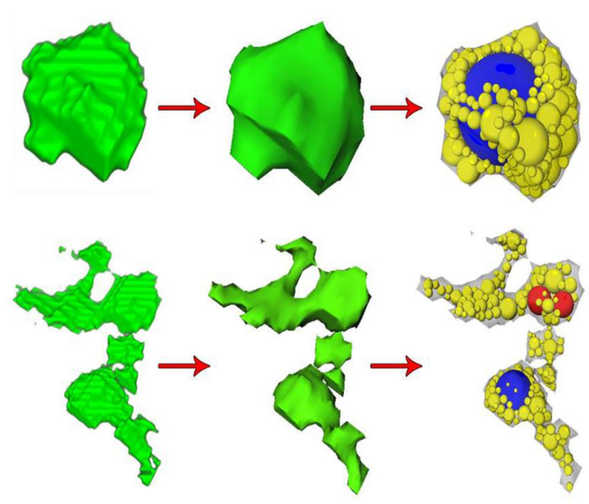
Preprocessing

1) Images sequence motion compensation.
2) ROI separated from the *t1-t0* subtraction image according the provided mask.
3) 3D segmentation using Mean Shift method.
4) Uniforming clusters' intensity range.
5) Thresholding and keeping only the clusters above the threshold.



Sphere Packing

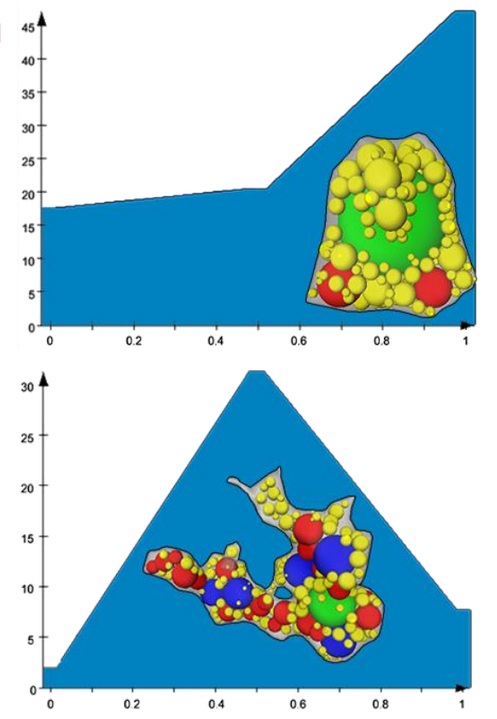
Sphere packing algorithm iteratively fills the lesion with a fixed number of non-overlapping spheres starting with the biggest possible radius, under the condition that they should completely locate inside the lesion.



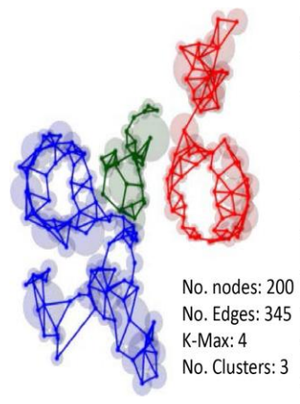
Feature Extraction

a) Volume-Radius Histogram

- **x-axis**: the radius ranges of internal spheres.
- **y-axis**: the sum of spheres' volumes with the radius falling into a bin.
- The number of bins is arbitrary.



b) Graph Features

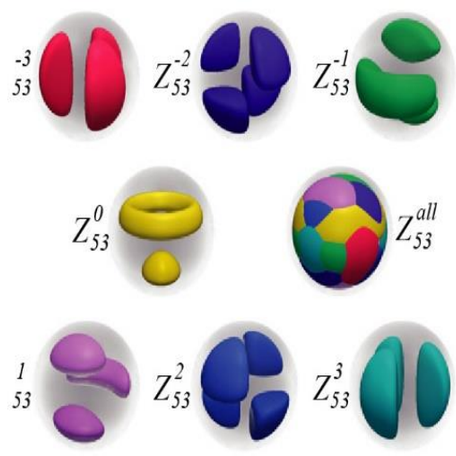


Feature	Value	Feature	Value
Edge Density	1.725	**Coverage**	0.57971013
Edge Density*	0.0086249998	**Modularization quality MQ**	-34.993408
Compactness Index Cp	0.24017853	New **MQ***	0.037906155
New Cp*	0.13441421	**Global Silhouette index (GS)**	0.48201945
Linear Structure (Stratum)	0.080078728	**New GS***	0.44905704
Dunn's Index	0.37598059	**Jaccard** Coefficient	0
Davies Bouldin	2.3165514	Folkes **and Mallows index**	0
MinMaxCut	0.0077294684	**Rand Statistic**	0.61100501
Cohesion	20.242949	Hubert and **Arabie's** statistic	0

We constructed several graphs, in which the center points of embedded spheres are considered as nodes, and spatial relationship between them as edges with weights according to their distance. Then global and local graph-based features were extracted.

c) 3D Zernike Descriptor

3D Zernike Moments are used to provide a compact numerical expression of the spatial features and derive robust invariant descriptors of 3D objects.



Evaluation

The evaluation is done using 10-fold cross-validation and Random Forest machine learning algorithm after applying **mean decrease accuracy (MDA)** feature selection. In differentiating between malignant and benign lesions, an **accuracy** of **90.56%**, **precision** of **90.3%**, and **area under the ROC curve (AUC)** of **0.94** is achieved.

Feature Selection method	No. Features	TP Rate		FP Rate		Precision		Accuracy		AUC	
		Ben.	Mal.	Ben.	Mal.	Ben.	Mal.	Ben.	Mal.	Ben.	Mal.
No selection	142	0.789	0.912	0.088	0.211	0.833	0.886	13.2%	86.79%	0.907	0.907
MDG	30	0.816	0.956	0.044	0.184	0.912	0.903	9.43%	90.56%	0.935	0.935
MDA	30	0.816	0.956	0.044	0.184	0.912	**0.903**	9.43%	**90.56%**	0.94	**0.94**