



Project Management and System Development

Activity Classification with Persistent Homology Barcodes

Final Presentation 25/07/2017

Project Supervisor: Benjamin Busam

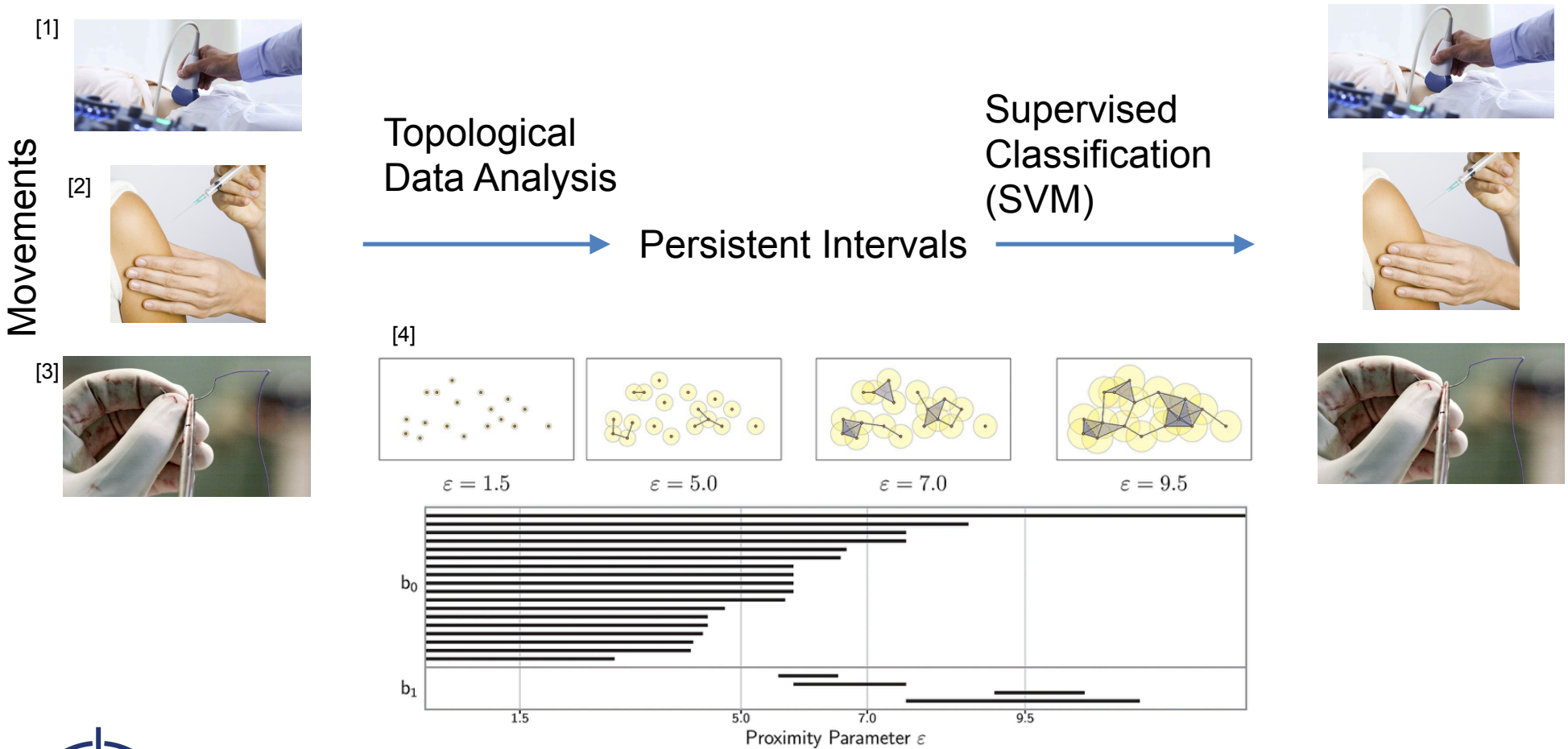
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Objective

- Classify repetitive movements according to distance measurement between them.



[1] [Image US](#) [24.7.17]

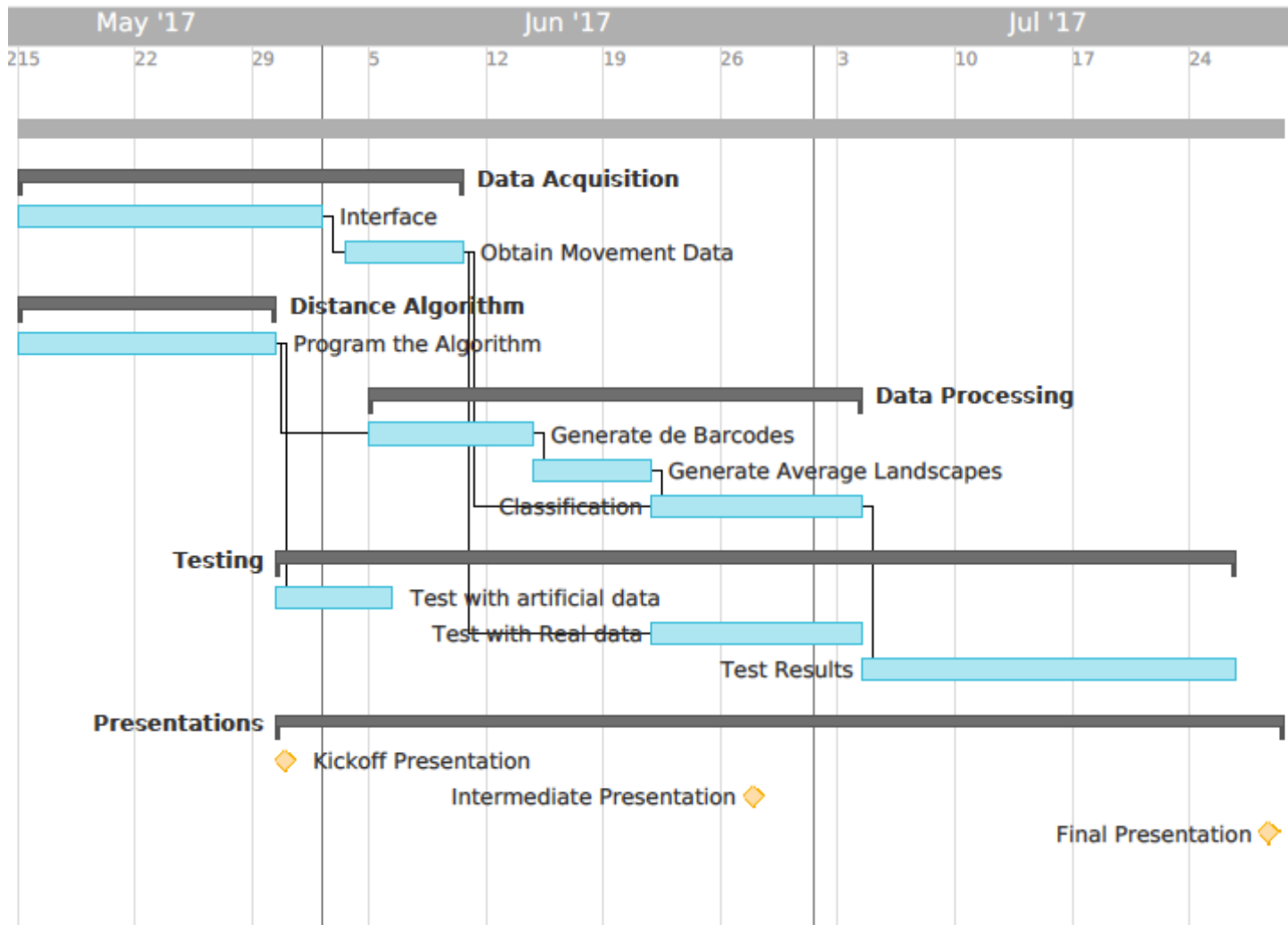
[2] [Image Needling](#) [24.7.17]

[3] [Image Sewing](#) [24.7.17]

[4] [Image Intervals](#) [24.7.17]

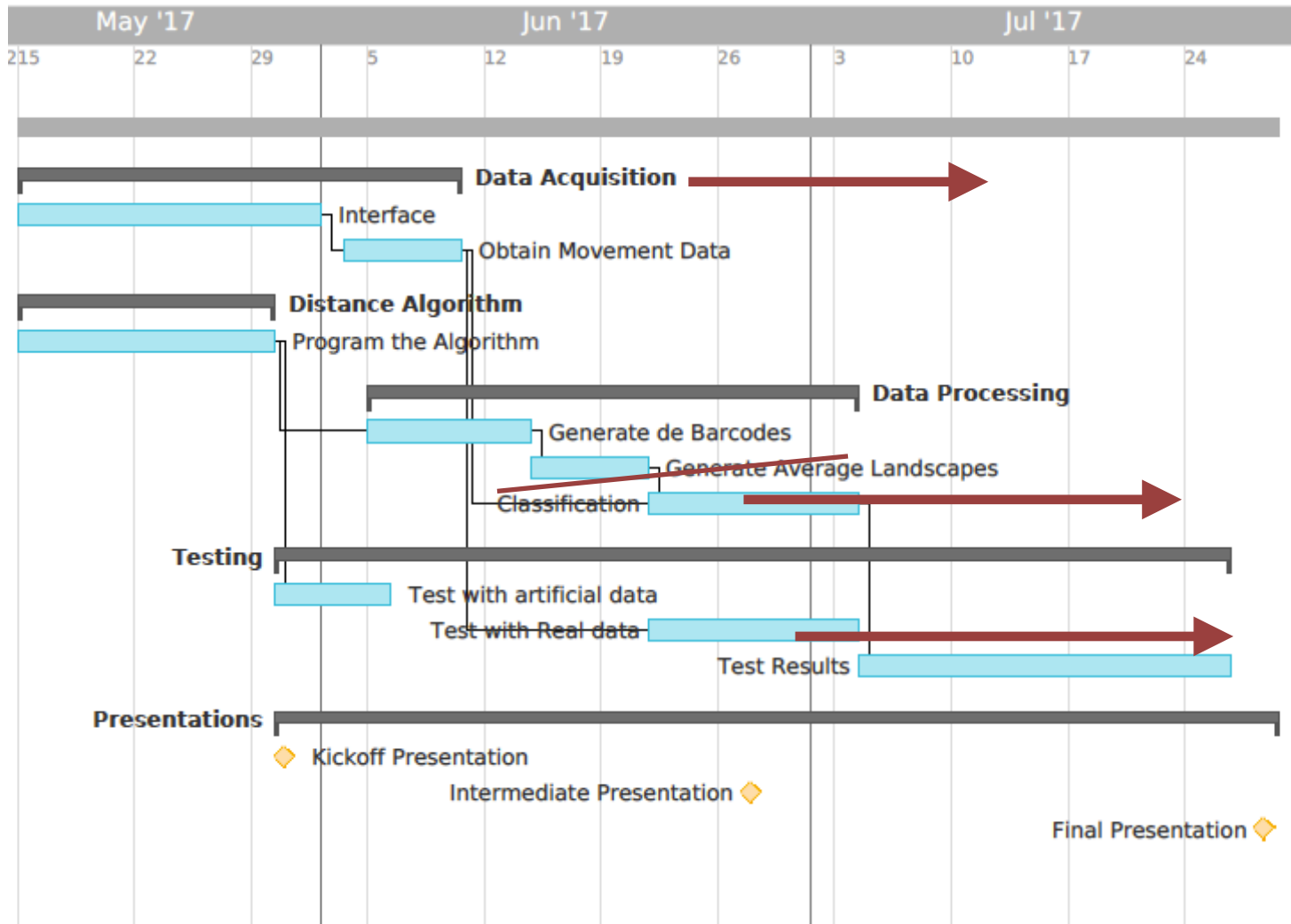


Project Overview: Initial Plan



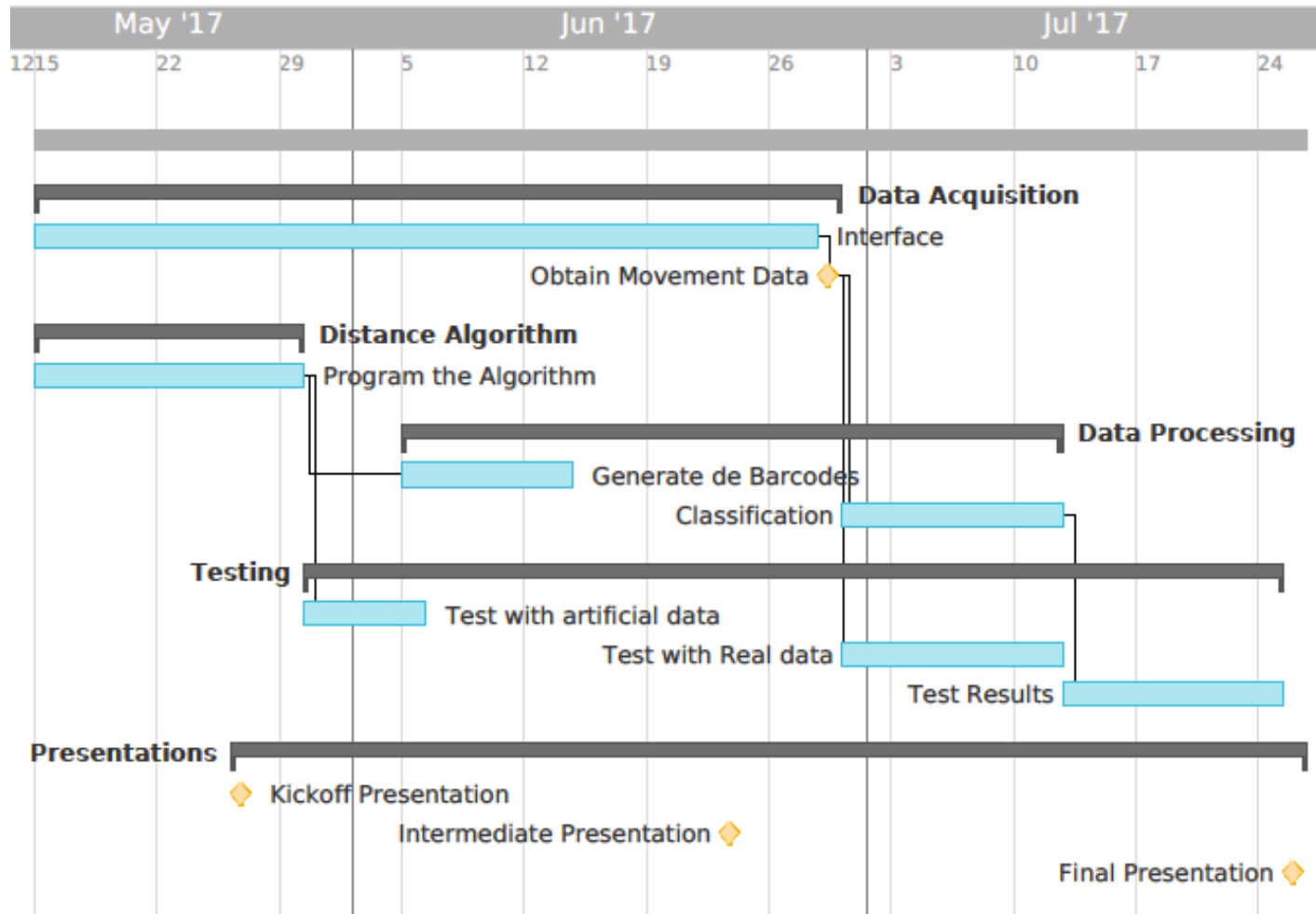
Made by [TeamGantt](#)

Project Overview: Intermediate Variations



Made by [TeamGantt](#)

Project Overview: Final Plan



Made by [TeamGantt](#)

Project Overview

Challenges

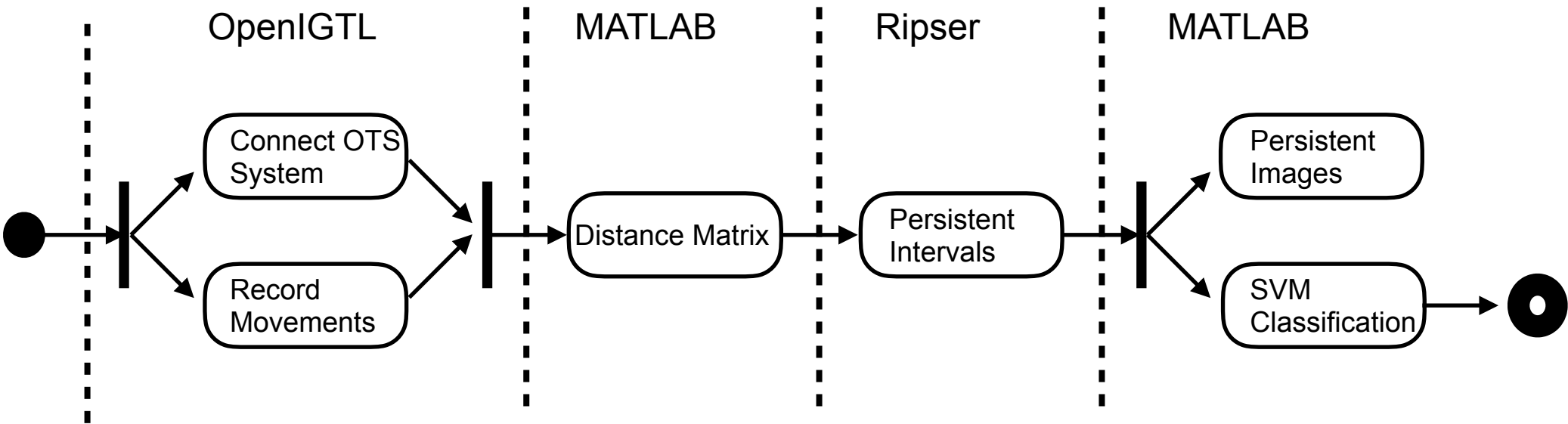
- Build the OpenIGTLink Library in C++
- Fail to integrate C++ Libraries / Matlab -> File based communication
- Parameter variation for optimal classification results.

Learning Outcome

- How does an Optical Tracking System (OTS) work.
- Usability of Persistent homology diagrams
- Implementation of supervised classification method.



Workflow

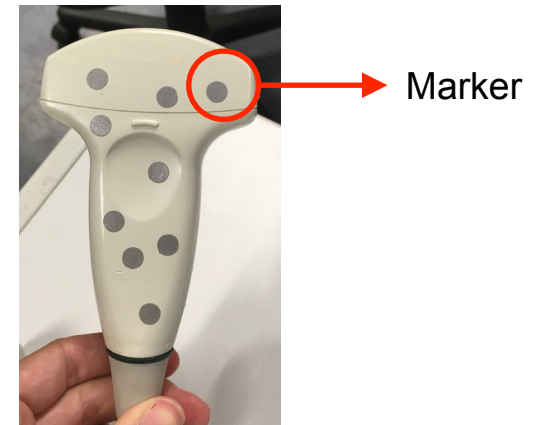


Workflow

1. Data retrieval from FRAMOS Optical Tracking System

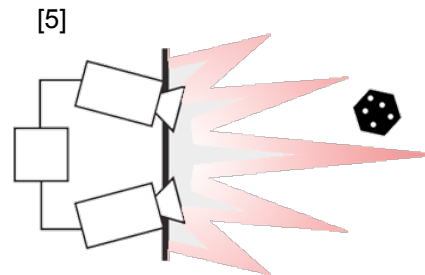
Six movements recorded twice with two repetitions each.
Two set of movements performed by two users

- Ultrasound
 - Abdomen
 - Ribs
 - Sentinel Lymph Node (SLN)
 - Carotid
- Sewing
- Needling

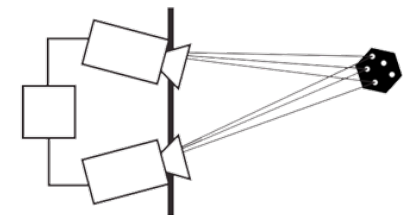


Acquisition Parameters:

- Tracking Frequency: 10Hz



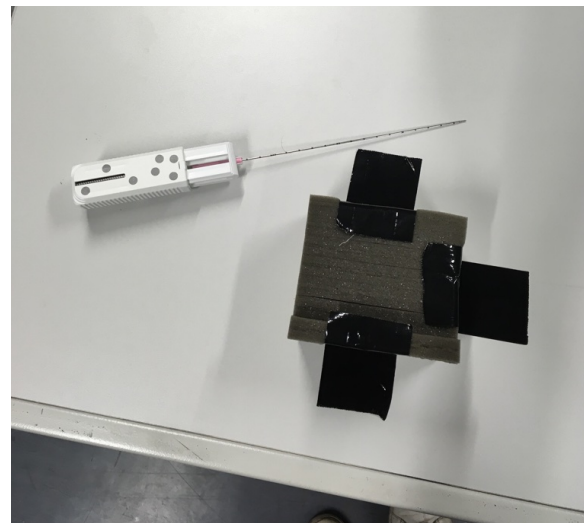
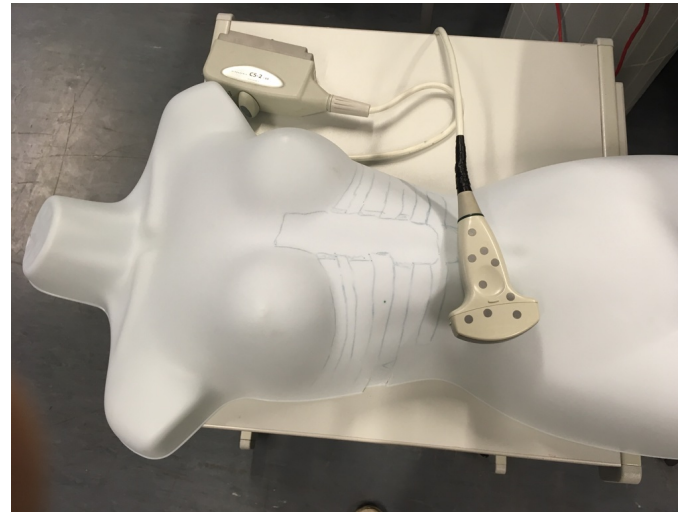
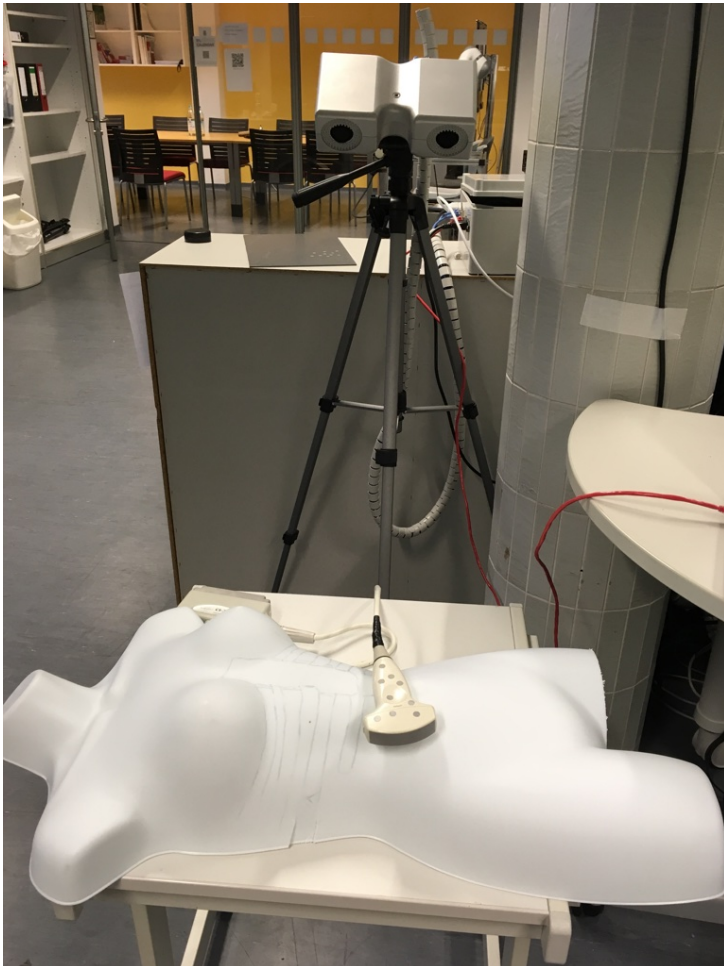
The object is lit using near IR light



Retro-reflective markers reflect back

Workflow

1. Data retrieval from FRAMOS Optical Tracking System



Workflow

2. Square Distance Matrix Calculation

Distance Algorithm generated with MATLAB

$$\begin{bmatrix} 0 & d_{w_1, w_2} & d_{w_1, w_j} \\ \vdots & \ddots & \\ 0 & \dots & 0 \end{bmatrix}$$

$$d(w_i, w_j) = \sum_{k=1}^{N-1} d(b_{i-k}, b_{j-k})$$

N = window size
i, j = [1, ..., T] (T: number of frames)
b = point
w = window

Window Size

Input: Pose matrices text file

Output: Distance Matrix saved in text file



Workflow

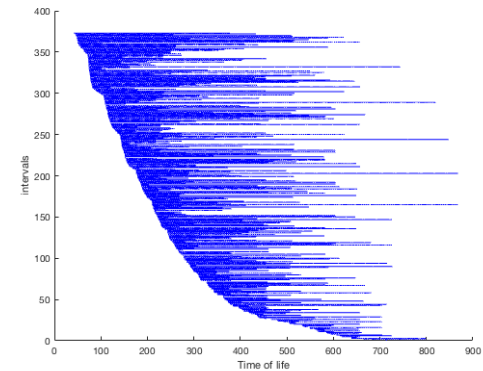
3.1. Homology Barcodes

Tool: Ripser Library

Input: Distance Matrix text file

Output: Persistent Intervals saved in text file

[6] ✓ Multi-scale description of the homological features

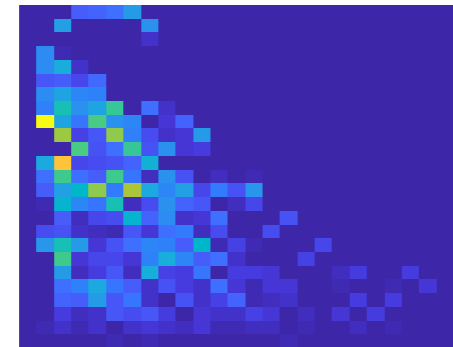


3.2 Persistent Images

Input: Persistent Intervals text file

Output: Displayed Image

[6] ✓ More visual interpretation
✓ Stability against small perturbations



6. H. Adams, S. Chepushtanova. 2015. *Persistence Images: A Stable Vector Representation of Persistent Homology*. Available [here](#) [24.7.17].

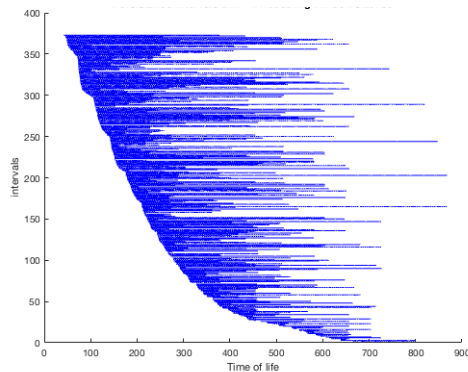
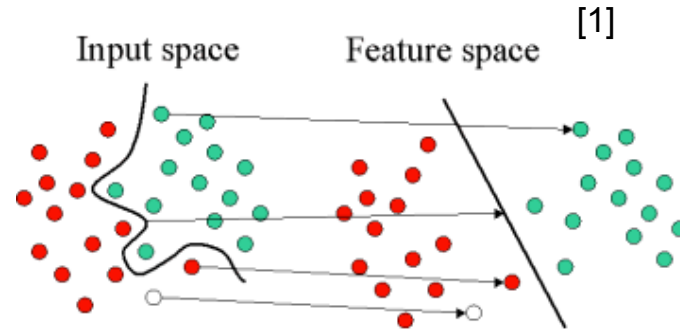
Workflow

4. Support Vector Machine (SVM) Classification

Supervised Learning Method.

Training Data 60%
Test Data 40%

Input: Persistent Intervals text file
Output: Confusion Matrix



SVM →

		Predicted class [2]	
		<i>P</i>	<i>N</i>
Actual Class	<i>P</i>	True Positives (TP)	False Negatives (FN)
	<i>N</i>	False Positives (FP)	True Negatives (TN)

Confusion Matrix

[7] [SVM Image](#) [24.7.17]

[8] [Confusion Matrix](#) [24.7.17]



Results

Classification Trials

- Between Sewing, Needling and Ultrasound
- Between Ultrasound modalities (Abdomen, Ribs, Carotid and SNL)
- Between Users

Parameters: Window Size

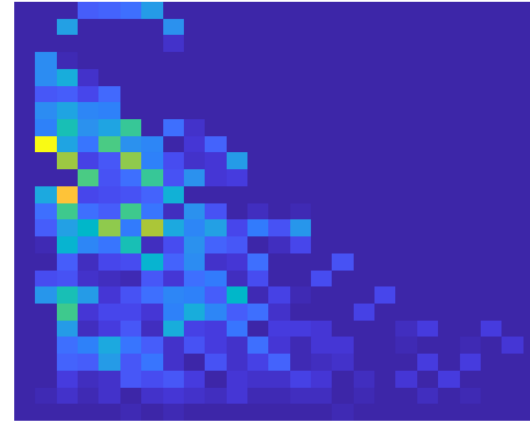
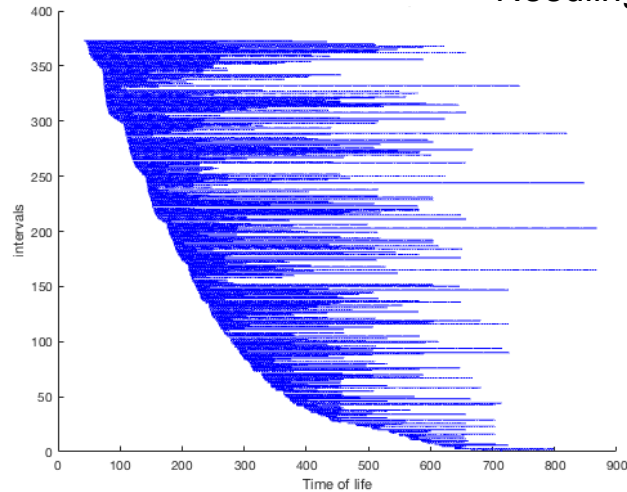
It Aims to get one repetition of the movement in a single window

- Needling: long movement, few repetitions. Big window
- Sewing: short movement, many repetitions. Small window
- Ultrasound: More complex. depends on modality.

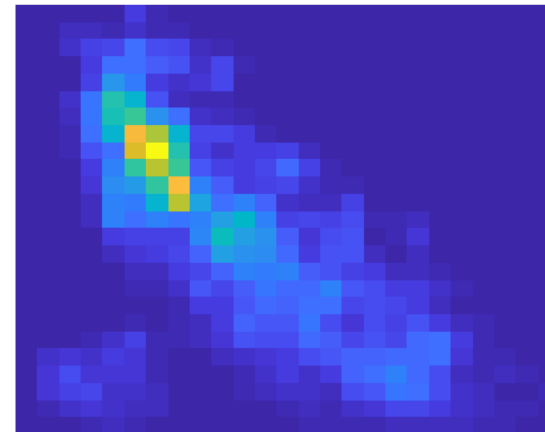
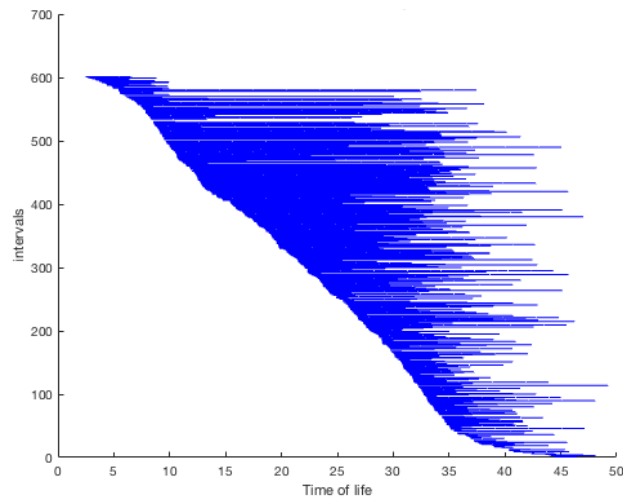


Persistent Intervals/Images. Needling and Sewing.

Needling. WindowSize = 50

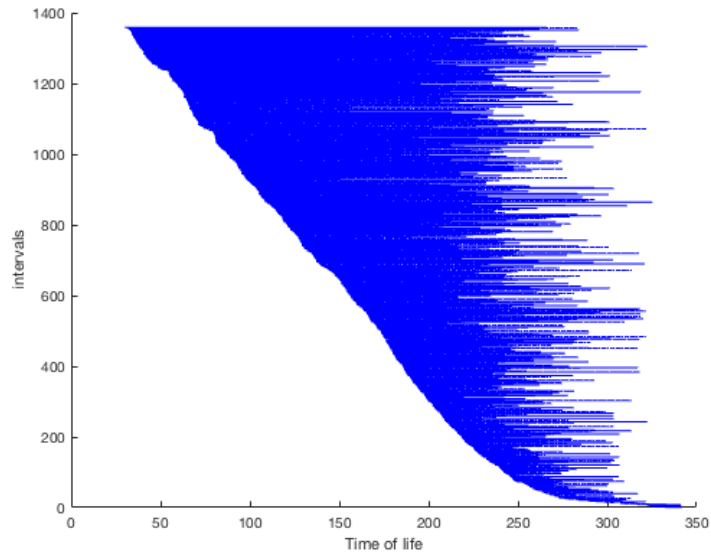


Sewing. WindowSize = 6

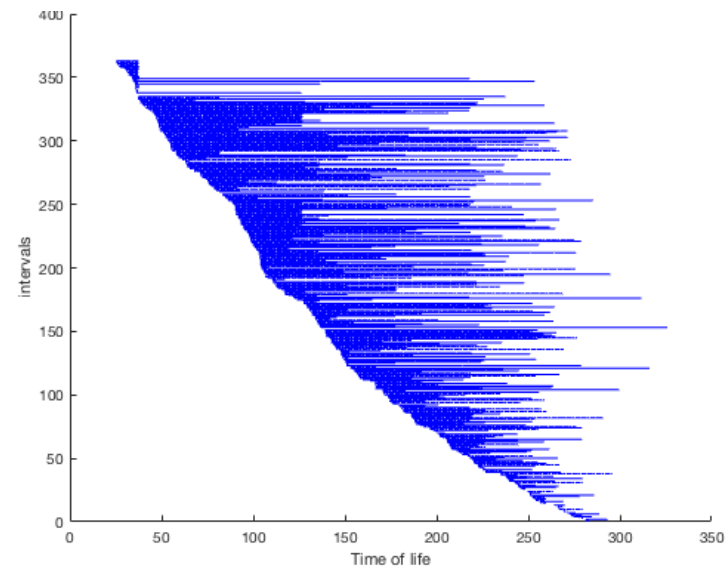


Persistent Intervals. Ultrasound (WindowSize = 30)

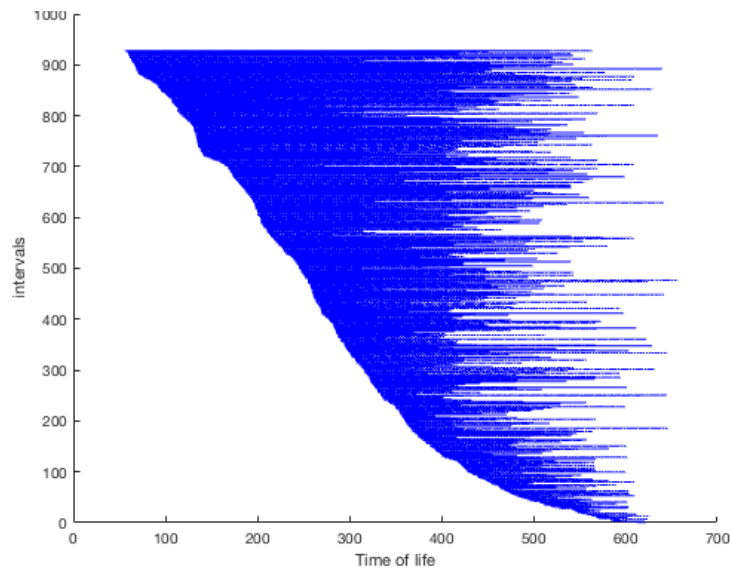
Abdomen



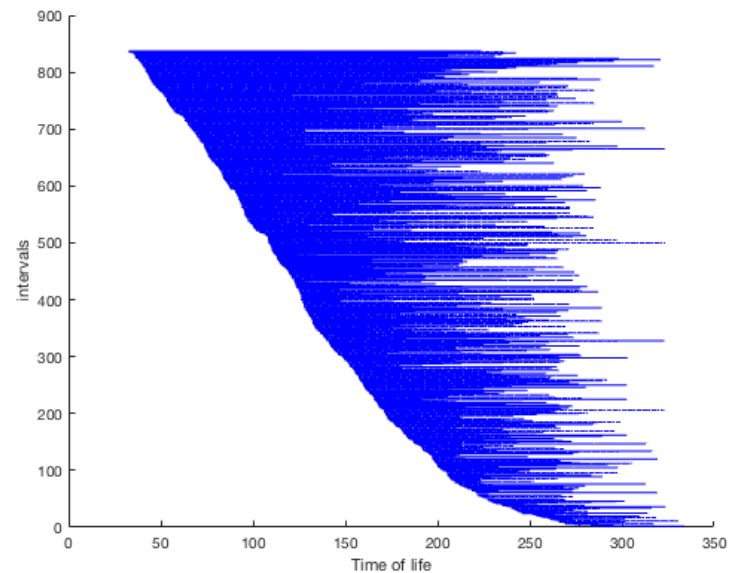
Carotid



Ribs

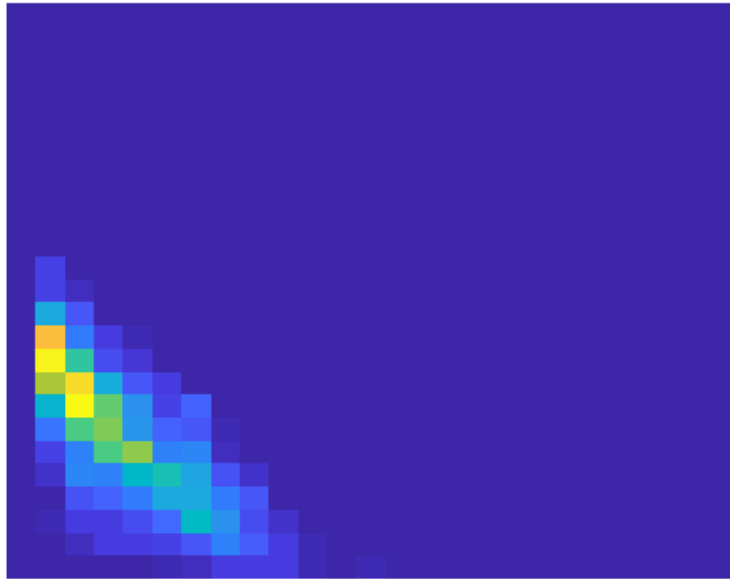


SLN

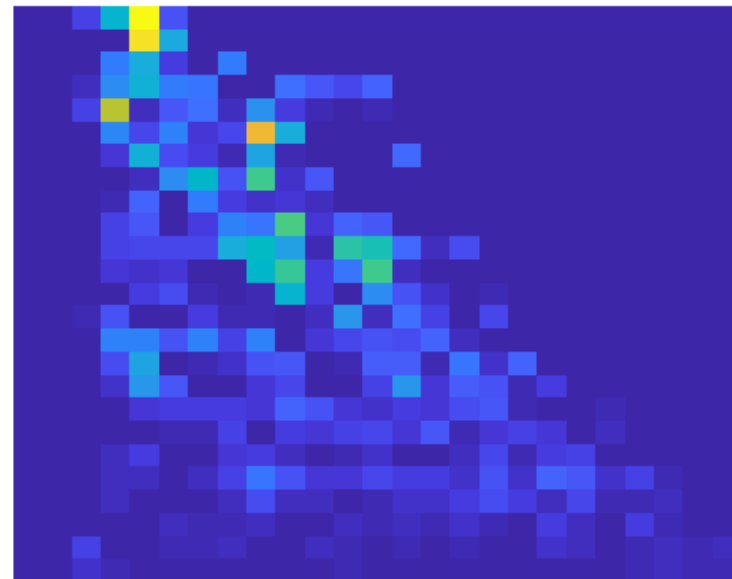


Persistent Images. Ultrasound (WindowSize = 30)

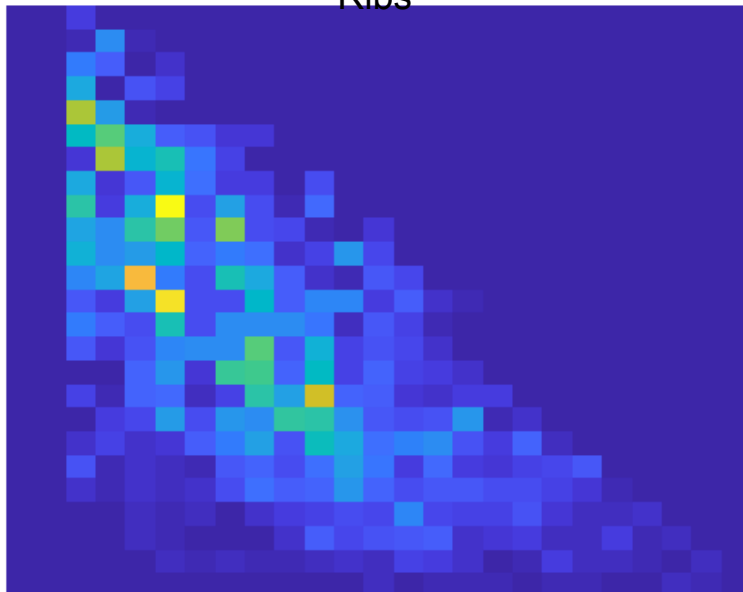
Abdomen



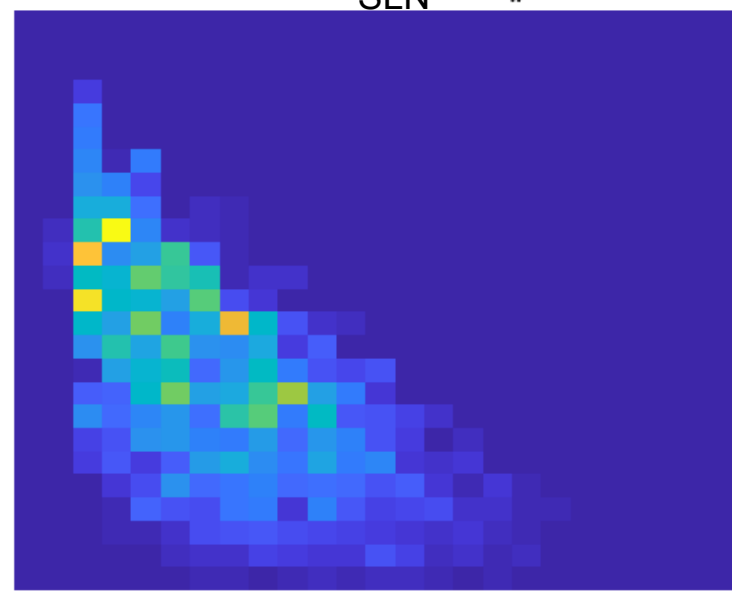
Carotid



Ribs



SLN



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Sewing, Needling and Ultrasound

%	Needling	Sewing	Ultrasound
Needling	34.4	9	56.7
Sewing	0	100	0
Ultrasound	0.06	1.06	98.9

Confusion Matrix (%)

- Needling. **W50**
- Sewing. **W6**
- Ultrasound / **Carotid. W30**

Number of data

- Needling: 794
- Sewing: 1863
- Ultrasound: 1633

Rows: Predicted Class
Columns: Ground truth



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Sewing, Needling and Ultrasound

%	Needling	Sewing	Ultrasound
Needling	43.2	5.3	51.5
Sewing	0	100	0
Ultrasound	0.13	6.65	93.21

Confusion Matrix (%)

- Needling. **W30**
- Sewing. **W6**
- Ultrasound / **Carotid W20**

Number of data

- Needling:1023
- Sewing:1863
- Ultrasound:1443

Rows: Predicted Class
Columns: Ground truth



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Sewing, Needling and Ultrasound

%	Needling	Sewing	Ultrasound
Needling	56.67	11.15	32.17
Sewing	0	100	0
Ultrasound	50.5	1.3	48.2

Confusion Matrix (%)

- Needling. **W30**
- Sewing. **W6**
- Ultrasound / **Ribs W20**

Number of data

- Needling: 1094
- Sewing: 1863
- Ultrasound: 1770

Rows: Predicted Class
Columns: Ground truth



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Ultrasound Modalities

%	Abdomen	Carotid	Ribs	SLN
Abdomen	71.1	10	10.5	8.4
Carotid	59.1	21.6	5.6	13.7
Ribs	33.7	4	57.6	4.8
SLN	65.2	17.25	8.51	9

Confusion Matrix (%)
All W30

Number of data

- Abdomen: 2367
- Carotid: 1414
- Ribs: 1633
- SLN: 1339

Rows: Predicted Class
Columns: Ground truth



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Users
 - Among ultrasound modalities

%	User1	User2
User1	60.55	39.44
User2	30.2	69.8

Confusion Matrix (%)
All W30

Number of test data

- User1: 2880
- User2: 1619

Rows: Predicted Class
Columns: Ground truth



Results SVM

Weak classifier (0-40%)
Regular classifier (40-700%)
Strong classifier (70-100%)

- Between Users

- Among Sewing

%	User1	User2
User1	63.48	36.52
User2	88.2	11.8

Confusion Matrix (%)
W6

Number of test data

- User1 : 690
- User2 : 1138

- Among Needling

%	User1	User2
User1	54	46
User2	98	2

Confusion Matrix (%)
W50

Number of test data

- User1 : 293
- User2 : 495



Rows: Predicted Class
Columns: Ground truth

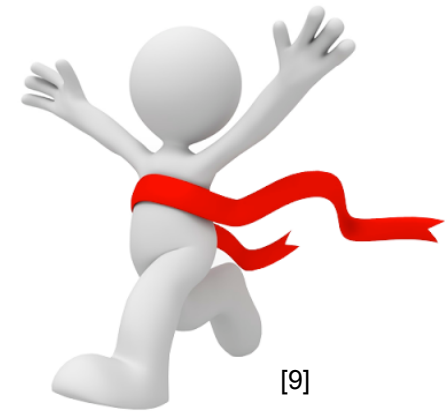
Results Interpretation

- Between Sewing, Needling and Ultrasound
 - Sewing is the most different and repetitive movement, hence the best classification rate.
 - Needling is a long movement not repetitive.
 - Carotid is the least varying ultrasound procedure.
 - Ultrasound is only repetitive in specific cases. Most complex action.
- Between Ultrasound Modalities
 - The method is not suitable
 - Abdomen seems the least similar modality.
- Between Users
 - Ultrasound is a more complex action -> Individual style
 - More simple and defined movements are user-independent -> Decision making



Conclusions

- Achievements
 - First trial of persistence homology in medical field.
 - Tool able to detect different, repetitive movements
 - Complex movements are more user dependent
- Advantages / Drawbacks of the Method:
 - ✓ Efficiently discriminates simple and very repetitive movements
 - ✓ Doesn't require a large amount of data
 - x Not suitable for complex and non repetitive movements .
- Future lines
 - Add a Rotation/Translation weight.
 - Record further movements
 - Implement it in real life applications.



[9]



[9] [Image](#) [24.7.17]

Questions?





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