Otolith age estimation by machine learning approaches

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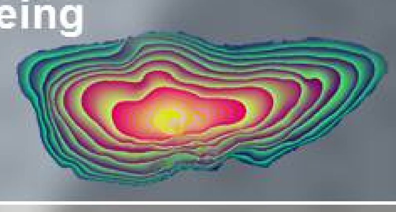
Otolith sampling and age estimation by Human experts

- Otoliths are paired calcified structures found in both inner ears of bony fish.
- Otoliths are used to determinate fish ages with different growth periodicities ranging from daily to annual increment.
- Between 800,000 and 1,000,000 otoliths are sampled and analysed per year
- Annnual cost of approximately $8 million
- The longest step in this process is the preparation and reading of otoliths by the experts.

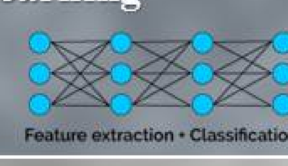
Automation of age reading ?

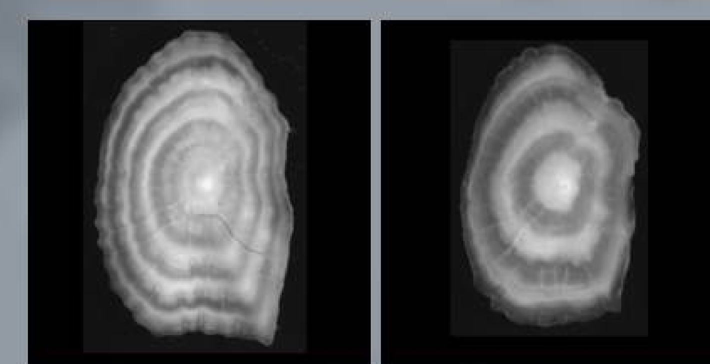
Automated FISh Ageing EU project (AFISA)



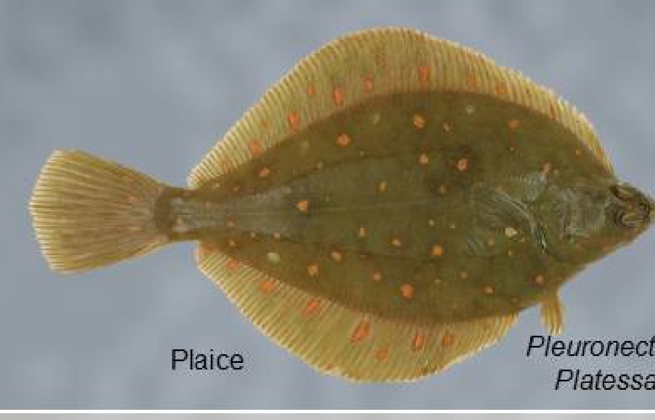
Mahé, 2009

Machine learning this study





Whole otolith images from plaice

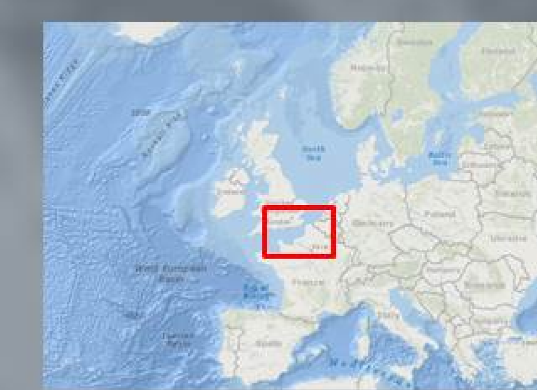


Plaice

Pleuronectes Platessa

8578 sampled Fishes

From surveys and fishing markets
Period: 2010 - 2017
Only Quarters 3 & 4
Age: from 0 to 8+ year classes



English Channel & Southern North Sea

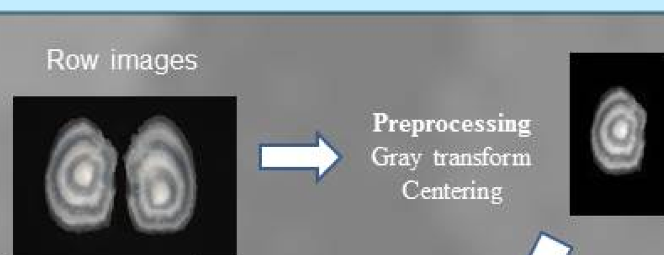
Training dataset : 5713 fishes
Including 20% validation

Test dataset : 2865 fishes

Age estimation by Machine

N=8523

Row images



Preprocessing
Gray transform
Centering

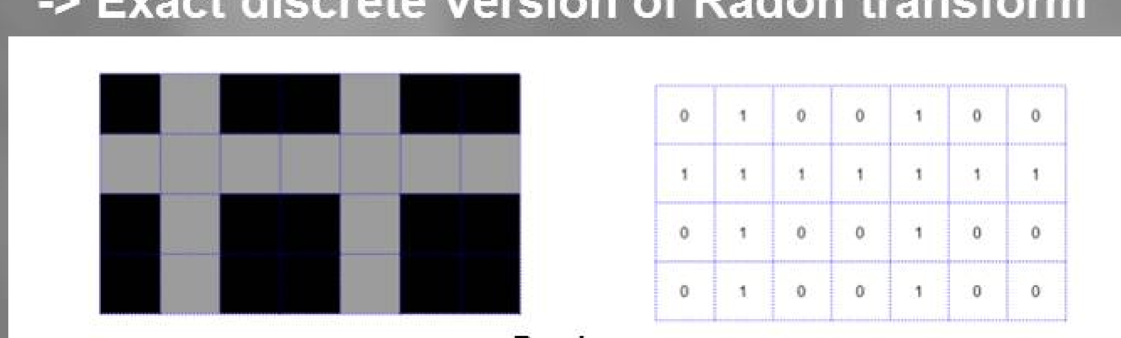
1 Resizing 1

Gray Image
40 pixels*40 pixels

2

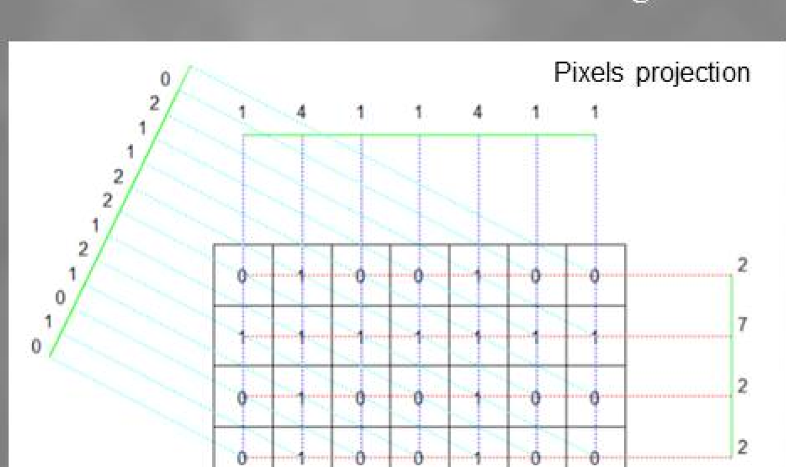
Mojette Transform

-> Exact discrete version of Radon transform



Row images

-> To reduce the information by recording only few projections that allow to reconstruct original image

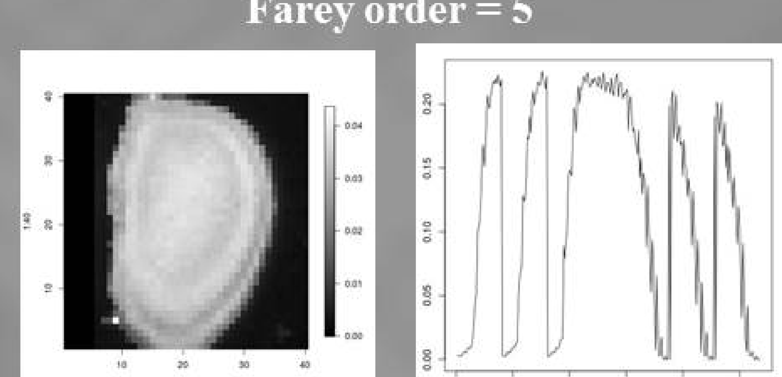


Each projection depends of its angle defined by (p,q) and it consists in a set of bin value M with b the index number of this bin.
All angles are built according to the Farey suite with n order and symmetry
A bin value M is the sum of pixel value f(i,j) according the direction characterized by (p,q).

Katz Criterion to select the number of projection :
sum(p) > P width or sum(q)> Q heigth.

$$M(b,p,q) = \sum_{i=-\infty}^{+\infty} \sum_{j=-\infty}^{+\infty} f(i,j) \times \triangle(b - p \times i + q \times j).$$

Farey order = 5



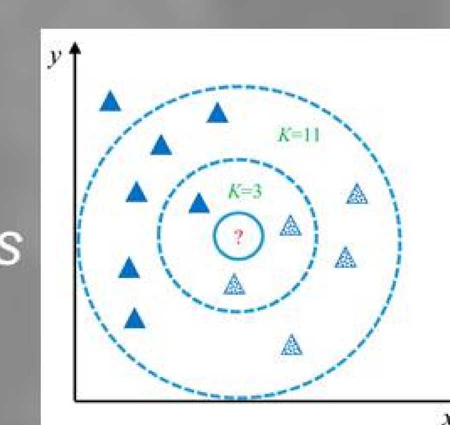
Row image

Projection 13

2

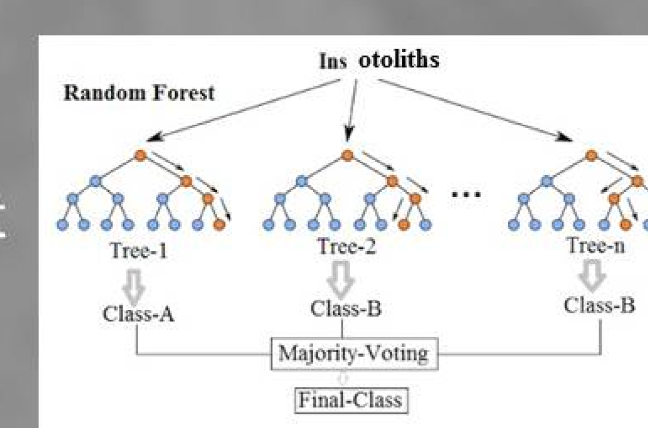
Machine Learning : 3 classifiers

k-NN
k-Nearest Neighbors



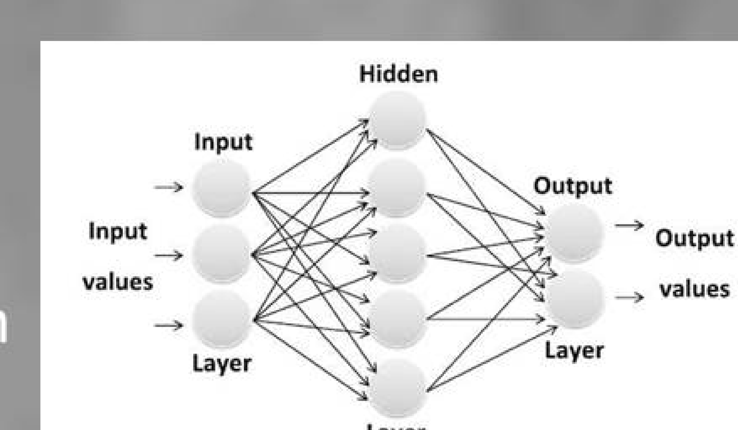
Library class

Random Forest



Library randomForest

MLP
Multi-Layer Perceptron



Library keras

Results

Human Expert

Age class	Training set	Test set
Age 0	116	49
Age 1	843	406
Age 2	1397	685
Age 3	1468	782
Age 4	1134	523
Age 5	419	237
Age 6	180	92
Age 7	130	54
Age 8+	71	37

Machine Learning

- k-nn : k=1/5/10
- Random Forest : mtry=16 ntree=50/100/500
- MLP : linear/1hidden layer 20 neurons/sigmoid function output :softmax activation 9 classes

% Agreement — k-NN, Random Forest, MLP

1

Database	Precision	1-nn	5-nn	10-nn	RF-50	RF-100	RF-500	Linear-MLP	20-MLP
Training	± 0 year	98,5	64,3	57,9	98,4	98,5	98,5	46,1	51,7
Training	± 1 year	99,5	88,6	87,1	99,5	99,5	99,5	84,3	87,8
Test	± 0 year	42,8	47,3	48,0	51,6	51,3	52,4	42,5	45,7
Test	± 1 year	79,6	84,2	85,2	88,7	88,9	89,2	83,0	85,5

2 Projections 12,13,15 & 16

Database	Precision	1-nn	5-nn	10-nn	RF-50	RF-100	RF-500	Linear-MLP	20-MLP
Training	± 0 year	98,5	61,6	55,7	98,5	98,5	98,5	45,8	43,5
Training	± 1 year	99,5	86,1	85,5	99,5	99,5	99,5	82,3	83,8
Test	± 0 year	42,8	45,7	45,9	49,6	50,8	51,3	40,6	41,5
Test	± 1 year	78,8	82,8	84,4	87,4	87,7	88,2	82,1	83,4

2 30 first Projections

Database	Precision	1-nn	5-nn	10-nn	RF-50	RF-100	RF-500	Linear-MLP	20-MLP
Training	± 0 year	98,5	63,5	57,1	98,4	98,5	98,5	-	47,7
Training	± 1 year	99,5	88,6	87,3	99,5	99,5	99,5	-	87,4
Test	± 0 year	43,7	45,5	47,6	50,7	51,7	51,9	-	44,6
Test	± 1 year	81,4	84,3	85,6	88,3	88,6	88,9	-	85,9

30 first projections
Random Forest Classifier
Test dataset : 2865 otoliths

51,9 % of Correct Classification

Predicted age (year) / Observed age (year)

Age group	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
Age 0	22	23	4	0	0	0	0	0	0
Age 1	4	303	84	9	6	0	0	0	0
Age 2	2	90	400	159	33	1	0	0	0
Age 3	3	24	169	439	145	2	0	0	0
Age 4	0	7	38	187	277	13	1	0	0
Age 5	0	1	9	33	152	35	2	5	0
Age 6	0	0	1	13	54	10	9	5	0
Age 7	0	1	0	8	29	4	11	1	0
Age 8+	0	0	1	7	16	3	3	7	0

± 0 year ± 1 year

Conclusion & Prospects

- ✓ Mojette transform results are very close to raw image analysis.
- ✓ k-sensibility in k-nn were correlated with the high intra-class variability and close inter-class size.
- ✓ Database size is not sufficient to build an efficient neuronal network (MLP).
- ✓ Random Forest seemed to be the best classifier according to raw image or Mojette bins.

- The database was built from all otolith images (n=8578) used for stock assessment without prior filtering or images cleaning -> image quality (broken otoliths, dirty otoliths) impacts the results and must be evaluated.
- These results could be improved by optimizing machine learning parameters and by selecting discriminant projections.

Contacts

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