2-D Shape Representation and Recognition by Lattice Computing Techniques

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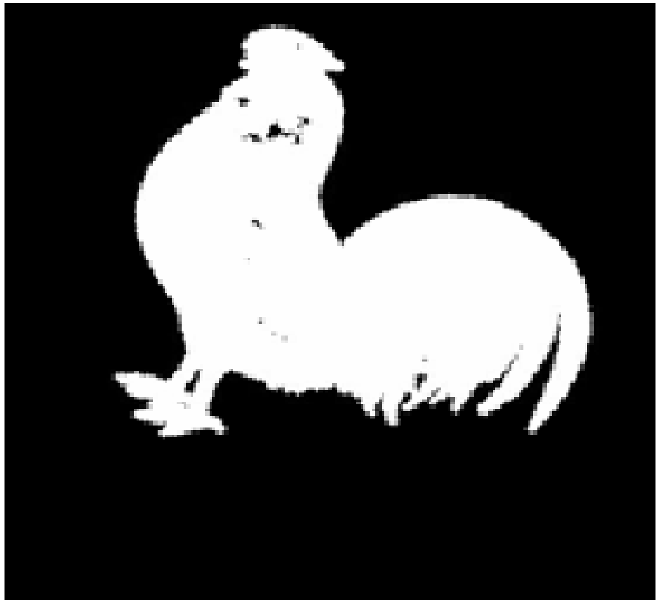
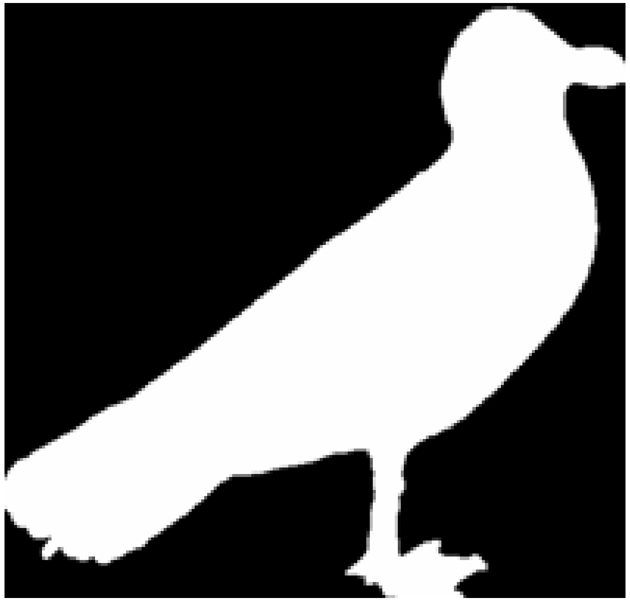
The Problem:
Classify 2-D Shapes in 70 classes …



(a) class “chicken”



(b) class “bird”

…from the MPEG-7 benchmark of binary images

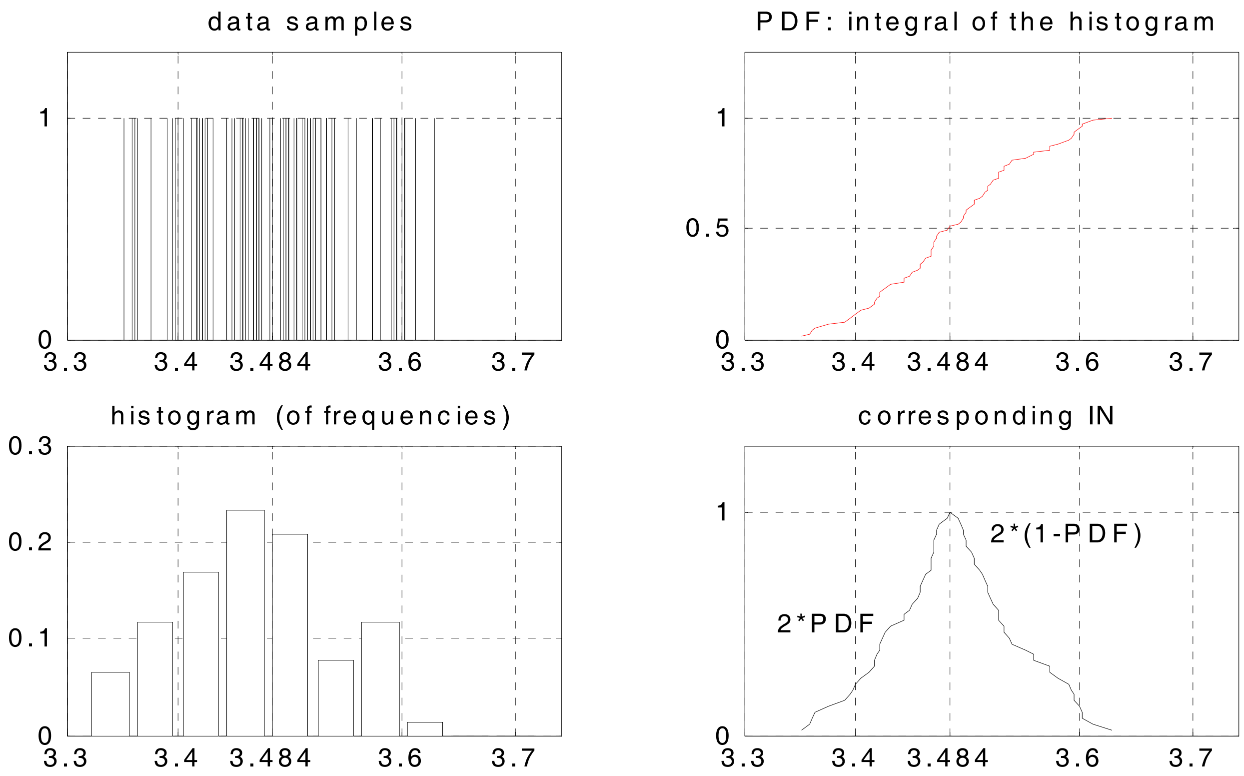
In a data pre-processing step, for each 2-D shape, we extracted three populations of *Descriptors** including

- N_{FD} = 32 Fourier Descriptors (FD),
- N_{ART} = 112 Angular Radial Transform (ART) Descriptors, and
- N_{IM} = 6 Image Moments (IM) Descriptors.

*A *Descriptor* is a real number.

- A population of Descriptors was represented by an Intervals' Number (IN) as follows.

IN representation of a Descriptors' population

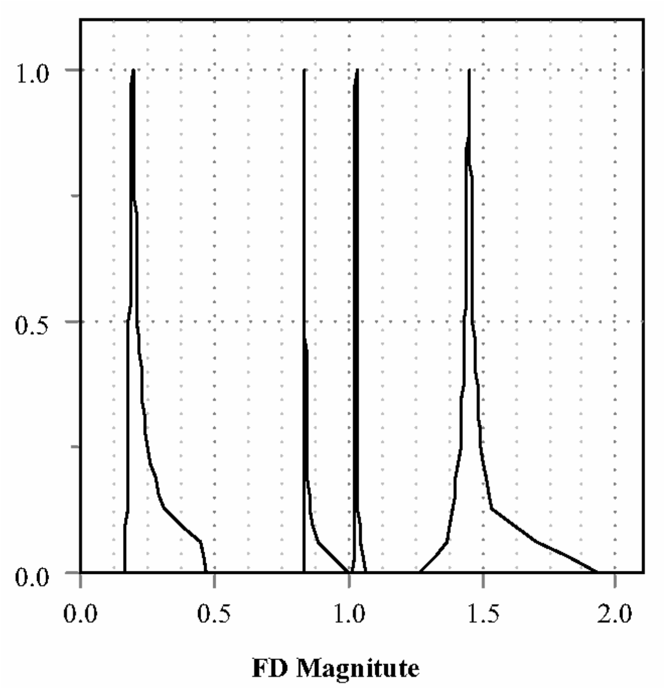


In conclusion,

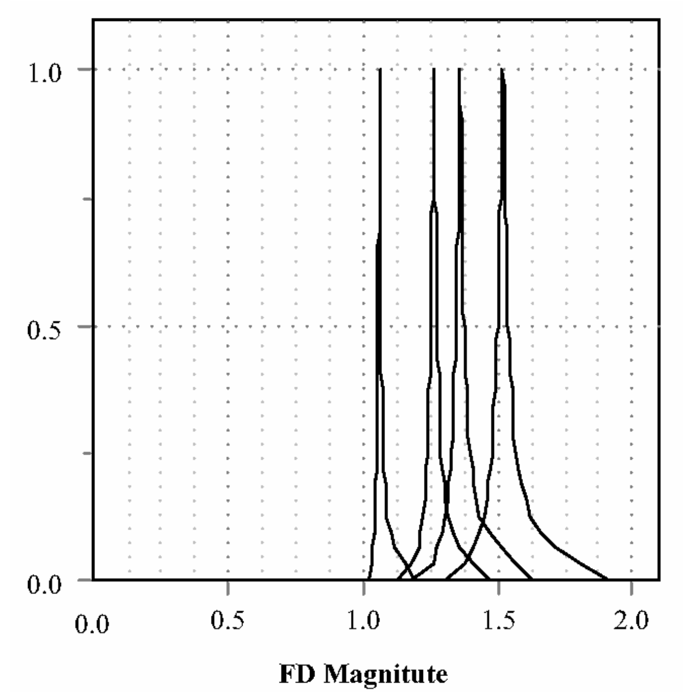
- a binary image was represented by three INs

Examples of INs induced from populations of Descriptors follow.

INs induced from FD descriptors

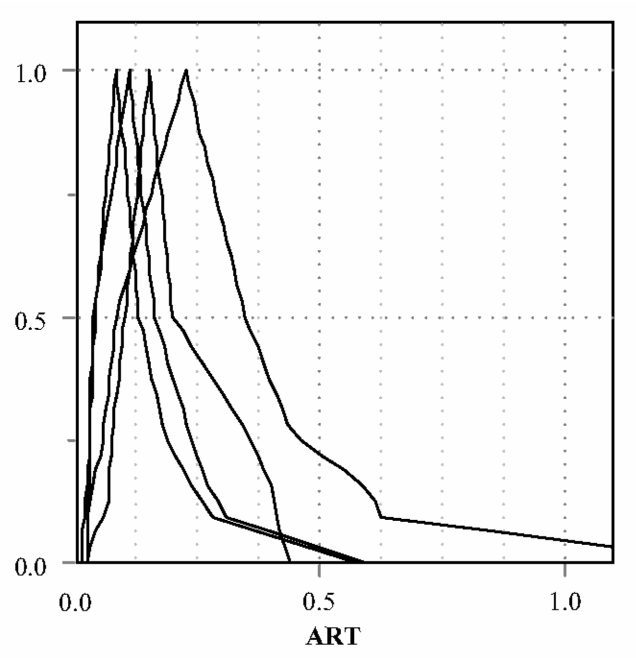


(a) INs for 4 “chicken”

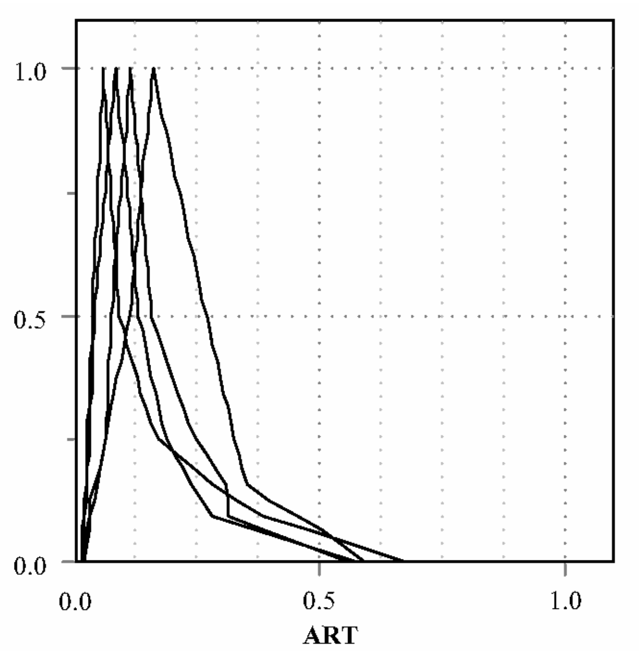


(b) INs for 4 “bird”

INs induced from ART descriptors

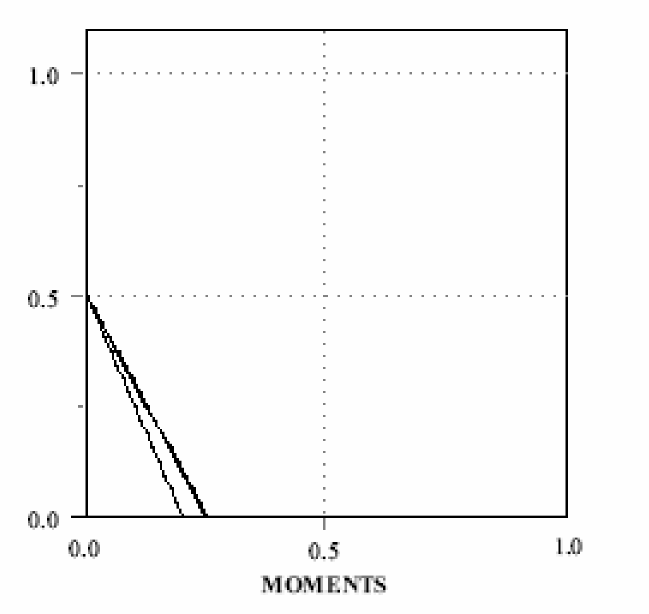


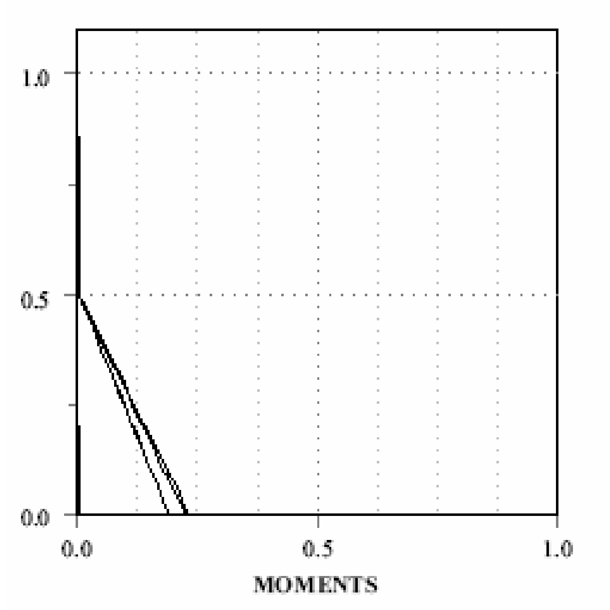
(a) INs for 4 “chicken”



(b) INs for 4 “bird”

INs induced from IM descriptors

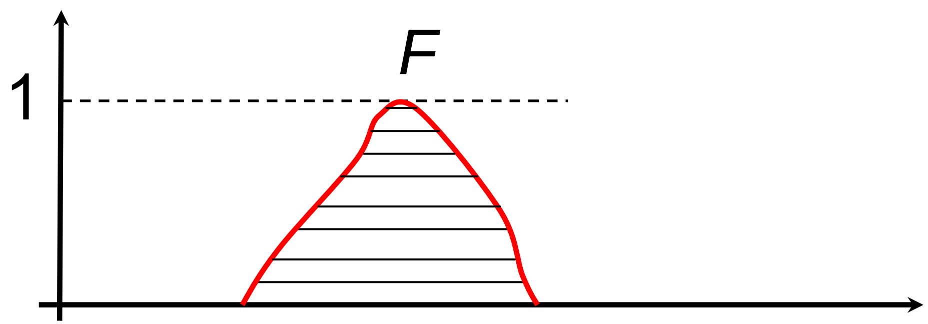




(a) INs for 4 “chicken” (b) INs for 4 “bird”

IN Representations & Mathematical Instruments

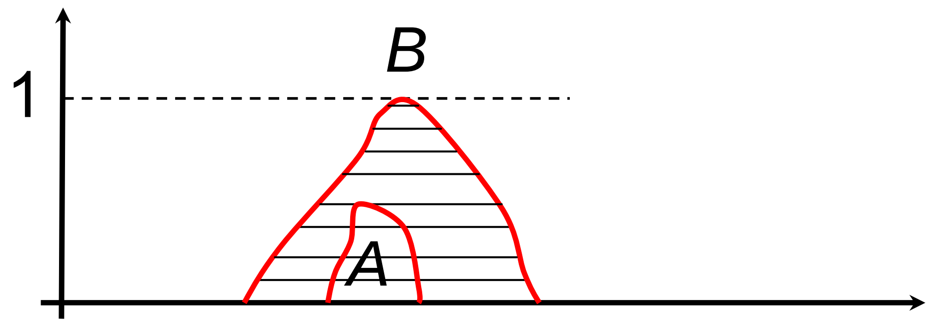
An Intervals' Number (IN) *F* can be represented, either by a *membership function* or, equivalently, by its (interval) α–cuts.



Let F denote the space of INs. Then,

- (F,$\leq$) is a complete lattice

An interval-IN



- The space of interval-INs is a complete lattice.

An *inclusion measure* function σ: $L \times L \rightarrow [0,1]$, in a complete lattice $(L, \leq)$ with minimum element O, by definition, satisfies conditions

1) $\sigma(x,O) = 0$, $x \neq O$.
2) $\sigma(x,x) = 1, \forall x \in L$.
3) $u \leq w \Rightarrow \sigma(x,u) \leq \sigma(x,w)$.
4) $x \wedge y < x \Rightarrow \sigma(x,y) < 1$.

An *inclusion measure* σ: $L \times L \rightarrow [0,1]$ is given by

either $$\sigma_{\vee}(x,y) = \sigma_{\vee}(x \le y) = \frac{v(y)}{v(x \vee y)}$$

or $$\sigma_{\wedge}(x,y) = \sigma_{\wedge}(x \le y) = \frac{v(x \wedge y)}{v(x)}$$

for either L=F or L=(lattice of interval-INs)

Cartesian Product Extensions

- Consider complete lattices $(L_i,\leq)$ each equipped with an inclusion measure function σ_i, $i\in\{1,\ldots,N\}$. Let $x=(x_1,\ldots,x_N),y=(y_1,\ldots,y_N)\in L=L_1\times\ldots\times L_N$. Then, both functions

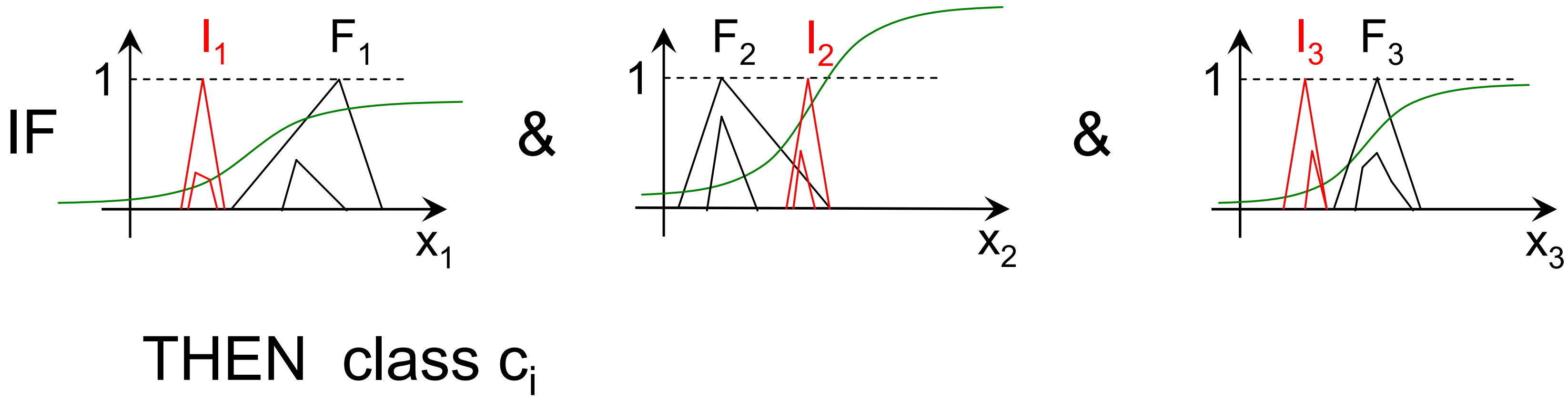
$$\sigma_{\wedge}(\mathbf{x}\leq\mathbf{y})=\min_{i}\{\sigma_i(x_i\leq y_i)\}\quad\text{and}$$

$$\sigma_{\prod}(\mathbf{x}\leq\mathbf{y})=\prod_{i}\sigma_i(x_i\leq y_i)$$

are inclusion measures.

Rule-Based Decision-Making

- The degree of membership of a red interval-IN in class c_i equals $\sigma((I_1,I_2,I_3)\leq(F_1,F_2,F_3))$.



- The *size* of an interval $[a_h,b_h]$ equals

$$S([a_h,b_h]) = v(b_h) - v(a_h),$$

- The *size* of a IN $F = [a_h,b_h]$, $h\in(0,1]$ equals

$$S(F) = \int_0^1 S([a_h,b_h])\,dh = \int_0^1 [v(b_h) - v(a_h)]\,dh$$

where function $v: R \to R$ is strictly increasing.

BIIN_{trn}: Batch Interval-IN for training

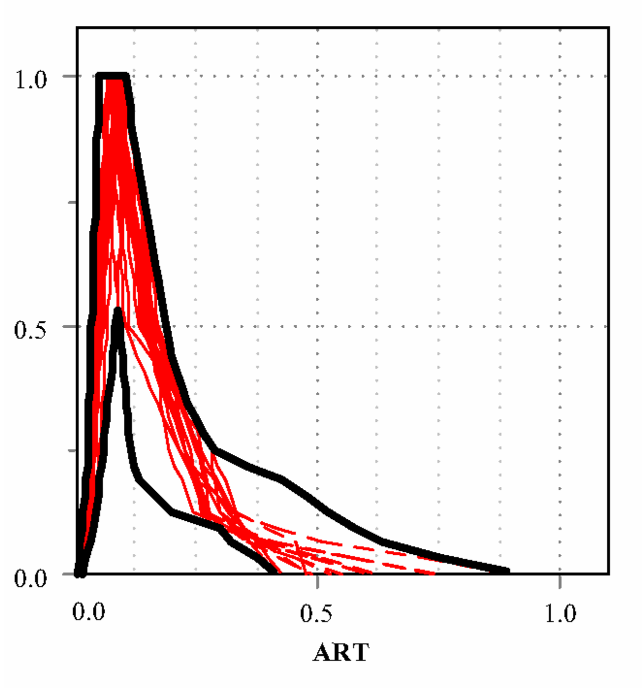
- Let $(\delta_1, c(\delta_1)),\ldots,(\delta_n, c(\delta_n))$ be labeled interval-INs for training.
- Consider a threshold S_θ.
- Let $(I,J)=\mathrm{argmin}\{S(\delta_i \vee \delta_j)\}$: $I \neq J$ and $c(\delta_I)=c(\delta_J)$.
- **while** $S(\delta_I \vee \delta_J) < S_\theta$ **do**
- Replace both δ_I and δ_J by $\delta_I \vee \delta_J$.
- Let $(I,J)=\mathrm{argmin}\{ S(\delta_i \vee \delta_j) \}$: $I \neq J$ and $c(\delta_I)=c(\delta_J)$.
- **end while**

$BIIN_{tst}$: Batch Interval-IN for testing

- Let $(\delta_1, c(\delta_1)), \ldots, (\delta_L, c(\delta_L))$ be labeled interval-INs.
- **For** i=1 to n **do** //for each testing datum IN E_i do
- J = argmax$\{\sigma[E_i, E_i] \leq \delta_\ell\}$, $\ell \in \{1, \ldots, L\}$.
- Assign IN E_i to the class $c(\delta_J)$.
- **end for**

- Preliminary Experiments and Results

Interval-INs computed from ART descriptors



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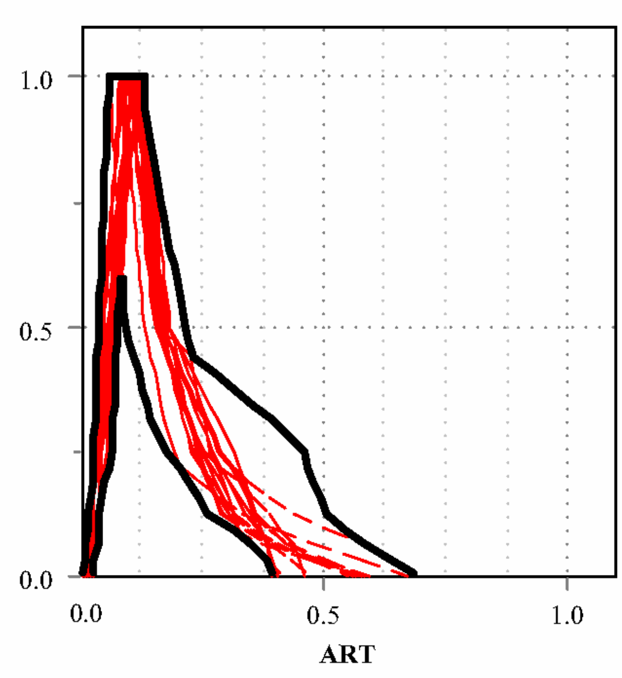

(b) class “bird”

- Recognition rates > 90%
- Comparative experimental work is under way.