



*7ème école d'été de Peyresq  
en traitement du signal et des images*

*Peyresq, du 24 au 30 juin 2012*

3D Shape Retrieval

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# Applications 3D

Cinema



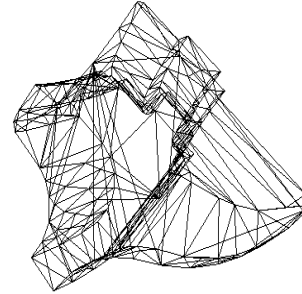
Video games



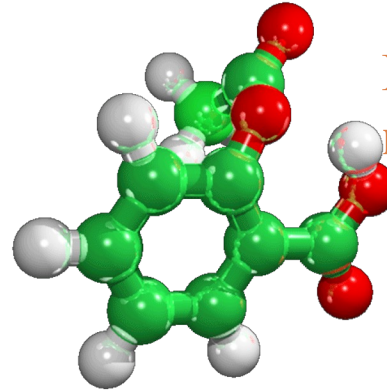
Biometric



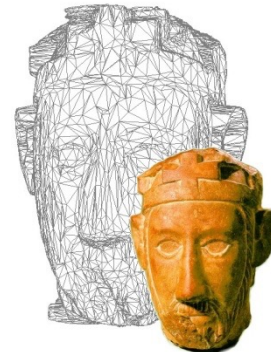
Computer Assisted Design



Biologie moléculaire



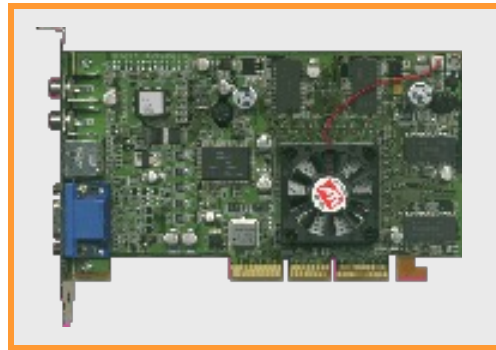
Cultural heritage



# Motivations



**Cheap scanners**



**Cartes Graphiques**



**World Wide Web**

**Someday 3D models will be  
as common as images are today**

# Challenge

Etant donné : Une base de modèles 3D et une requête

Chercher : Les k modèles 3D similaires à la requête.

The image shows a screenshot of a web browser window. On the left, a Google search page is visible with the search term '3d shape' and several search results. The main part of the browser displays the Semantic3D website. The website has a navigation menu with 'Main', 'Contact', 'Links', 'FAQ', and 'Team'. Below the navigation, there is a search bar and a 'Number of results by page' dropdown set to '16'. The main content area shows a grid of 16 3D model thumbnails, each with a small 'f' icon and a play button. A sidebar on the left of the Semantic3D page lists various categories like 'Princeton', 'Building', 'Airplane', 'Insect', 'Human', 'Animal', 'Underwater Creature', 'Blade', 'Body Part', 'Building', 'Chess', 'Computer Display Device', 'Door', 'Furniture', 'Liquid Container', 'Musical Instrument', 'Plant', 'Shoe', 'Tool', 'Vehicle', 'Wheel', and 'Other'.

# Plan

- Pourquoi la 3D ?
  - ▣ Applications de la 3D
  - ▣ Pourquoi la recherche par le contenu 3D ?
  - ▣ Critères d'évaluation des moteurs de recherche 3D.
  - ▣ Architecture d'un moteur de recherche 3D
- Différentes approches de recherche 3D
- Approche statistique
  - ▣ Spectre de courbure
  - ▣ Notion d'histogrammes de spectre de courbure
  - ▣ Distances entre spectre de courbures

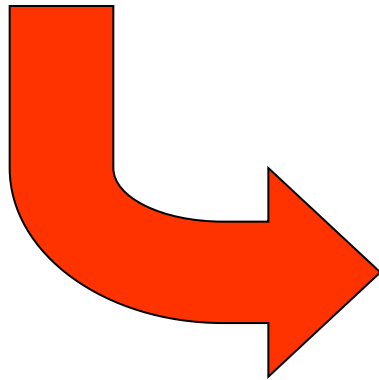
# Recherche par le contenu 3D

en 2D



- **Forme 3D**
- **Couleur**
- **Texture**

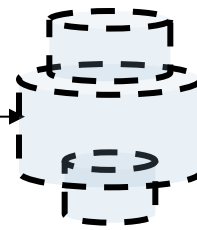
en 3D



# Analyse de contenu 3D



Analyse de la forme



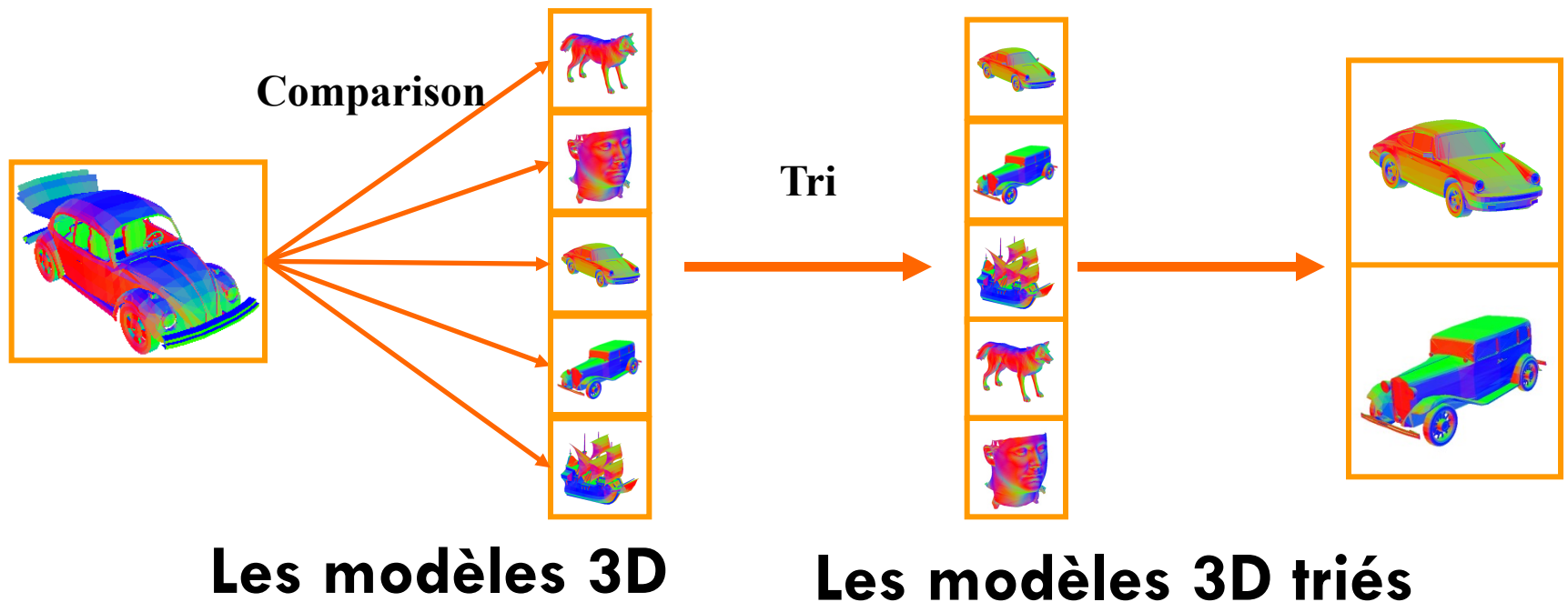
Requête en 3D



Résultats

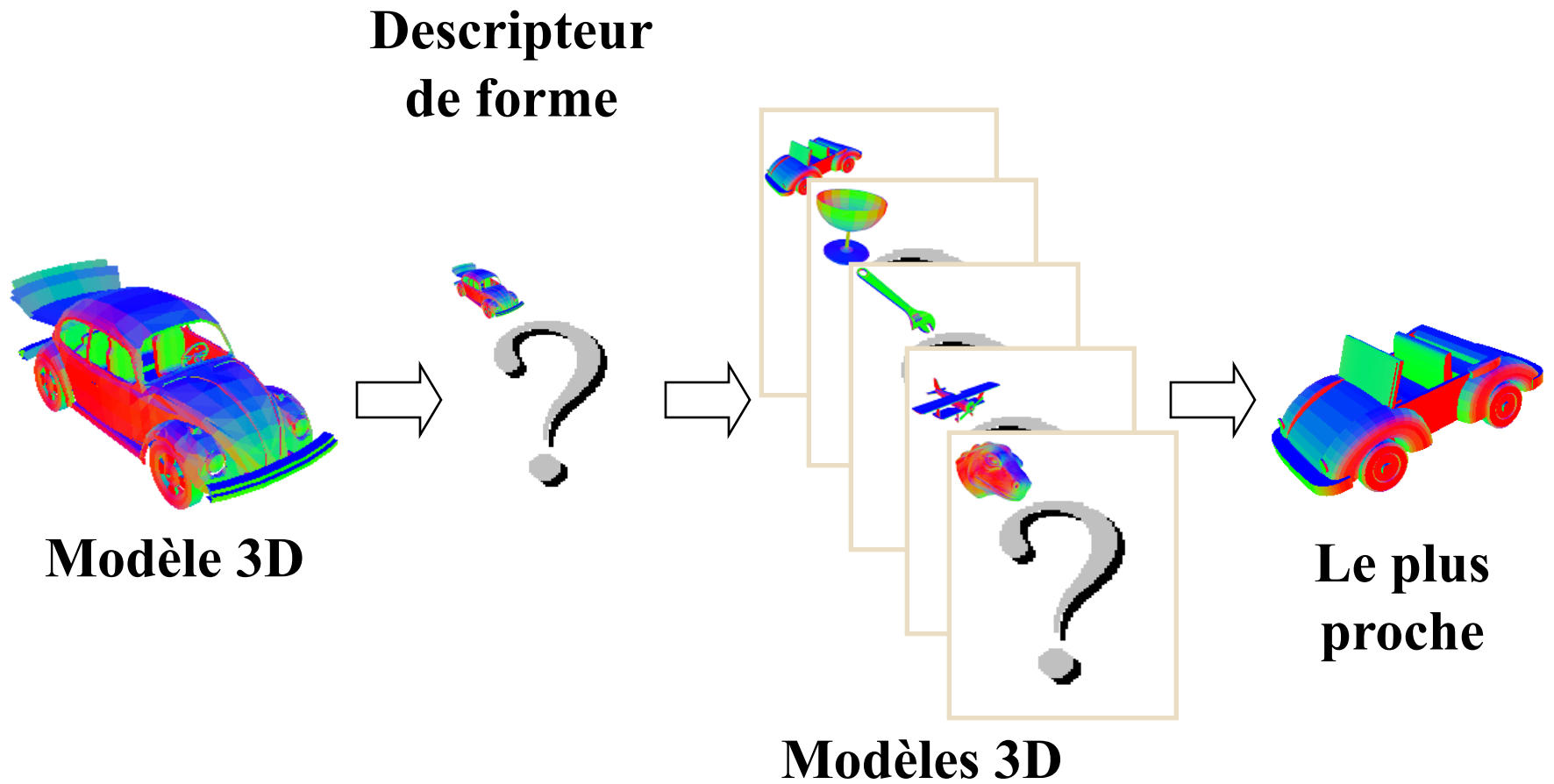
# Approche

- Calculer la distance entre la requête et les modèles 3D.
- Trier les distances.
- Retourner les k premiers.





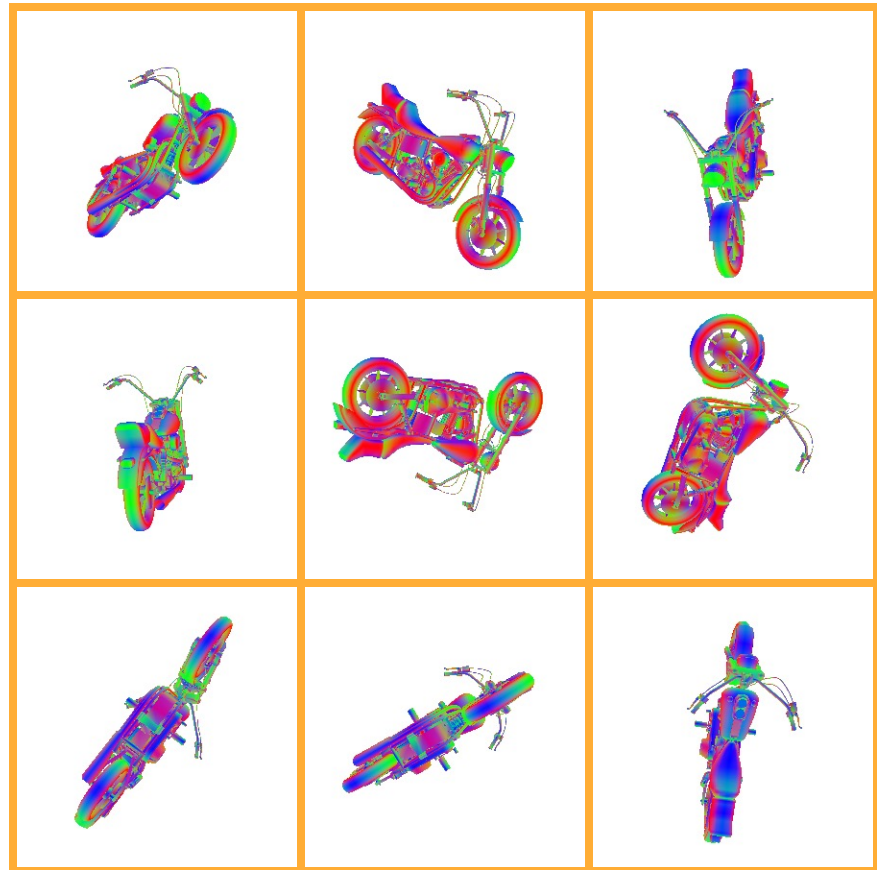
# Approche



# Invariance du descripteur de forme



=



# 3D retrieval by example

The screenshot displays a web browser window at the URL <http://www-rech.eric.fr:8080/3Dretrieval/>. The page features a navigation menu with links for [Main](#), [Contact](#), [Links](#), [FAQ](#), and [Team](#). A logo for "SEMANTIC 3D" is prominently displayed, along with a "fox-wire LIFL" logo. A login section includes fields for "Login" and "Password" with a "Log" button, and a link to "Create your account".

On the left side, a sidebar menu titled "All Databases" lists various categories such as "building", "Airplane", "insect", "human", "Animal", "underwater\_creature", "Blade", "body\_part", "Building", "Chess", "computer\_display\_device", "Door", "furniture", "liquid\_container", "musical\_instrument", "plant", "Sea", "tool", "vehicle", "wheel", and "other". The "plant" category is currently selected.

The main content area shows a search results grid. At the top of this area, there is a "Number of results by page" dropdown menu set to "16". Below this, a 4x4 grid of 16 3D model thumbnails is displayed. Each thumbnail shows a different 3D model of a tree or plant on a grid floor against a blue background. Below each thumbnail are three small icons: a magnifying glass, a globe, and a document.

# 3D Retrieval from Photos

The screenshot displays the SEMANTIC 3D website interface. On the left, a sidebar contains a search interface with three image thumbnails of bicycles, each with a 'Load' button and a checked checkbox. A 'Search' button is also present. The main content area features the 'fox-mire LIFL' logo and the 'SEMANTIC 3D' logo. Navigation links include 'Main', 'Contact', 'Links', 'FAQ', and 'Team'. A login section with 'Login' and 'Password' fields and a 'Log' button is located in the top right. Below the navigation is a 'Number of results by page' dropdown set to '16'. The main display is a 4x4 grid of 16 3D models, including various bicycles, a house, a bench, a ladder, and other objects. Each model is accompanied by a small set of icons (a magnifying glass, a globe, and a play button).

# 3D Search from Sketch

The screenshot displays a web browser window at the URL <http://www-rech.enic.fr:8080/3Dretrieval/>. The page features the **fox-mire** LIFL logo and the **SEMANTIC 3D** branding. Navigation links include **Main**, **Contact**, **Links**, **FAQ**, **Team**, and **Create your account**. A login section with fields for **Login** and **Password** and a **Log** button is also present.

On the left side, there is a **ToolBox** with drawing tools and a **Search** button. Below the toolbox, a sketch of a dog is shown in a wireframe view. The main content area displays a grid of 3D model thumbnails. Above the grid, a dropdown menu indicates the **Number of results by page** is set to **16**.

The grid contains 16 thumbnails, each showing a 3D model on a blue grid background. The models include various breeds of dogs (e.g., a brown dog, a white dog, a grey dog, a black dog), a grey dog lying down, a white horse, a brown bear, a person in a white and purple outfit, a brown horse, a white horse, a person in a yellow and black outfit, a grey hand, a red and white object, a yellow and white horse, a person in a green shirt and blue pants, and a white humanoid figure.

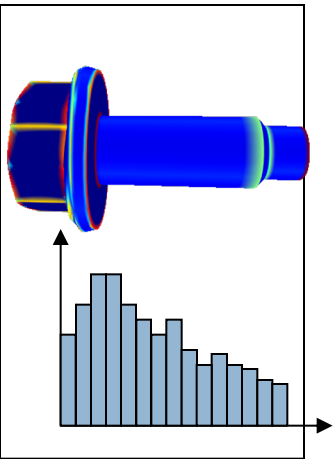
# 3D Search from Sketch

The screenshot displays the SEMANTIC 3D website interface. At the top, the browser address bar shows the URL <http://www-rech.enic.fr:8080/3Dretrieval/>. The website header includes the *fox-miire* LIFL logo, the SEMANTIC 3D logo, and navigation links for [Main](#), [Contact](#), [Links](#), [FAQ](#), [Team](#), and [Create your account](#). A login section with fields for "Login" and "Password" and a "Log" button is also present.

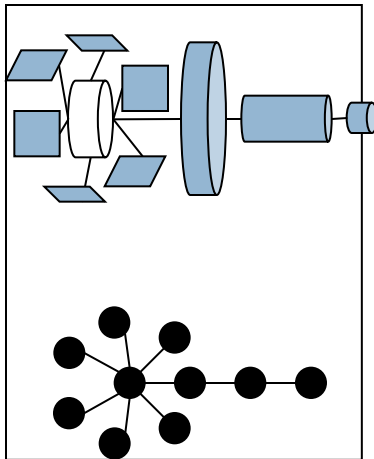
On the left side, there is a "ToolBox" with drawing tools and a "Search" button. Below the toolbox, a stick figure sketch is shown in a preview window. The main content area displays a grid of 16 3D human models, each with a small icon below it. The models represent various human figures in different poses and colors, including a white figure, a blue and black figure, a purple and brown figure, a white figure, a purple and white figure, a black figure, a yellow figure, a grey figure, a red and white figure, a white figure, a white figure, a white figure, a cyan figure, a white figure, a blue and red figure, and a white figure lying down. A dropdown menu above the grid indicates "Number of results by page 16".

# 3D Retrieval Approaches

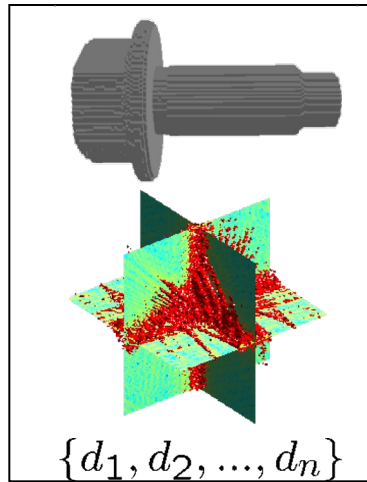
Statistical



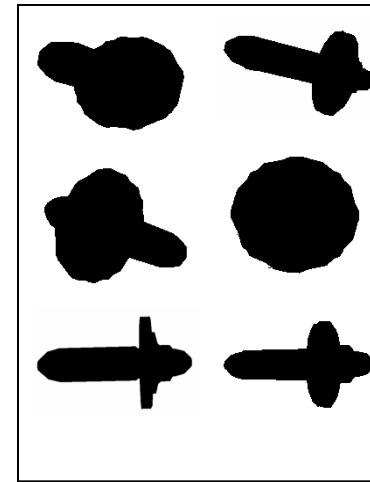
Structural



Transform



Views



Bag-of-feature



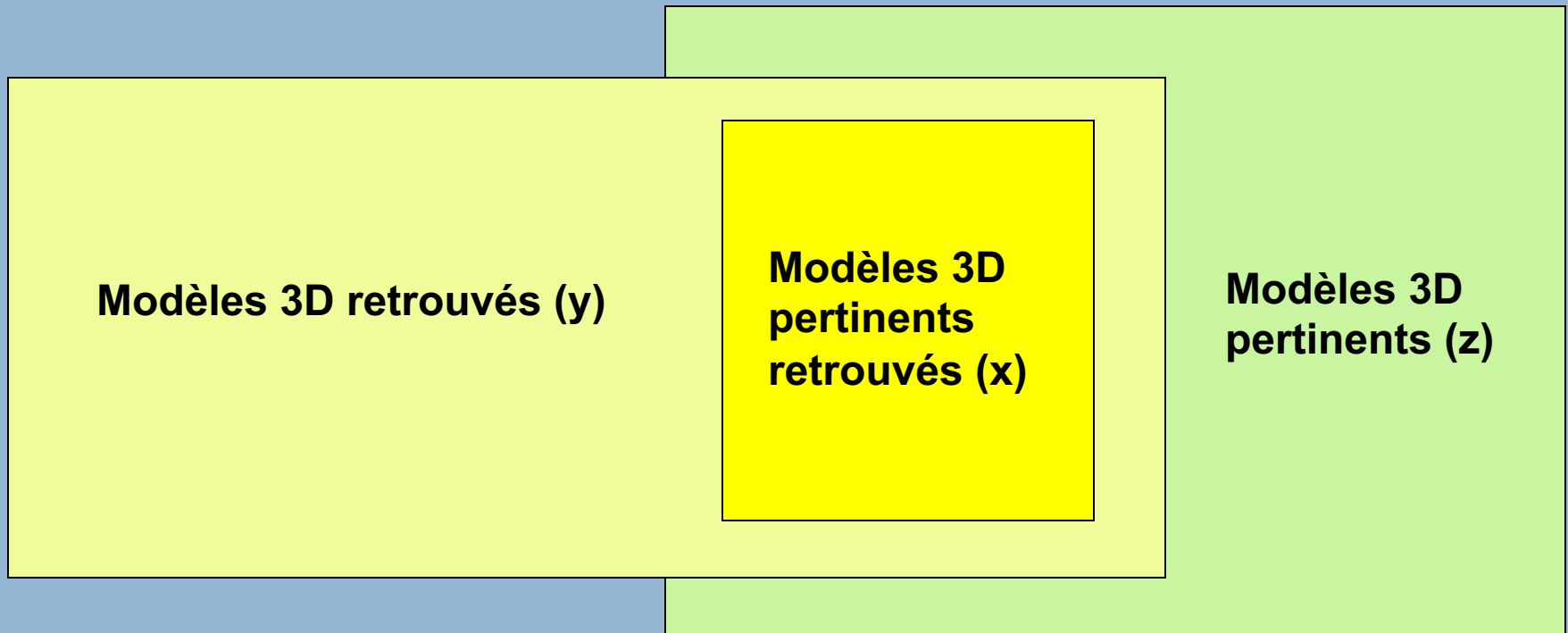
- pertinence
- taille
- vitesse

# Evaluation moteur de recherche

## Rappel/précision

16

Collection de tous les modèles 3D



Modèles 3D retrouvés (y)

Modèles 3D  
pertinents  
retrouvés (x)

Modèles 3D  
pertinents (z)

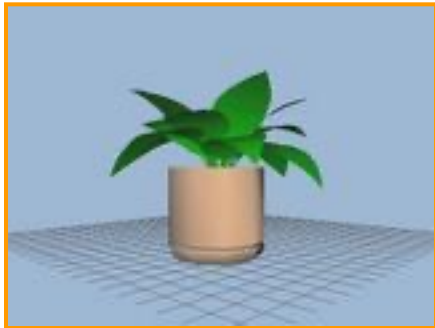
$$\text{Précision: } p = \frac{x}{y}$$

$$\text{Rappel: } r = \frac{x}{z}$$

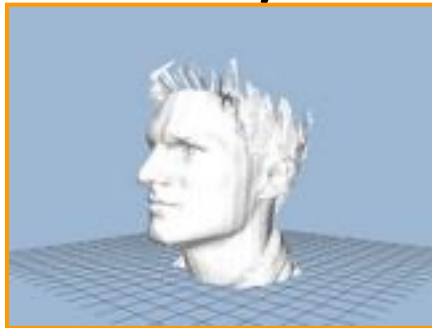


# Princeton Shape Benchmark

- 1814 classified models, 161 classes
- Evaluation metrics, software tools, etc.



**51 potted plants**



**33 faces**



**15 desk chairs**



**22 dining chairs**



**100 humans**



**28 biplanes**



**14 flying birds**

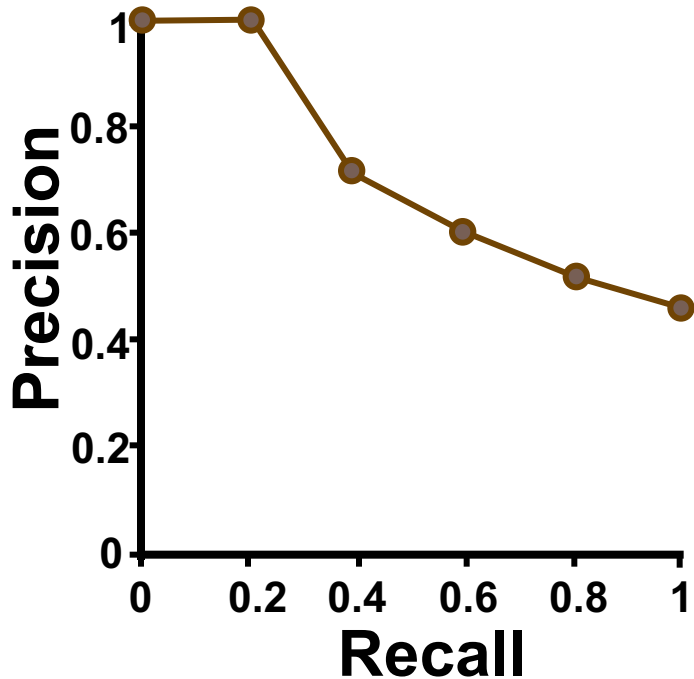


**11 ships**

# Precision vs. Recall

## Precision-recall curves

- $\text{Recall} = \frac{\text{retrieved\_in\_class}}{\text{total\_in\_class}}$
- $\text{Precision} = \frac{\text{retrieved\_in\_class}}{\text{total\_retrieved}}$



Query

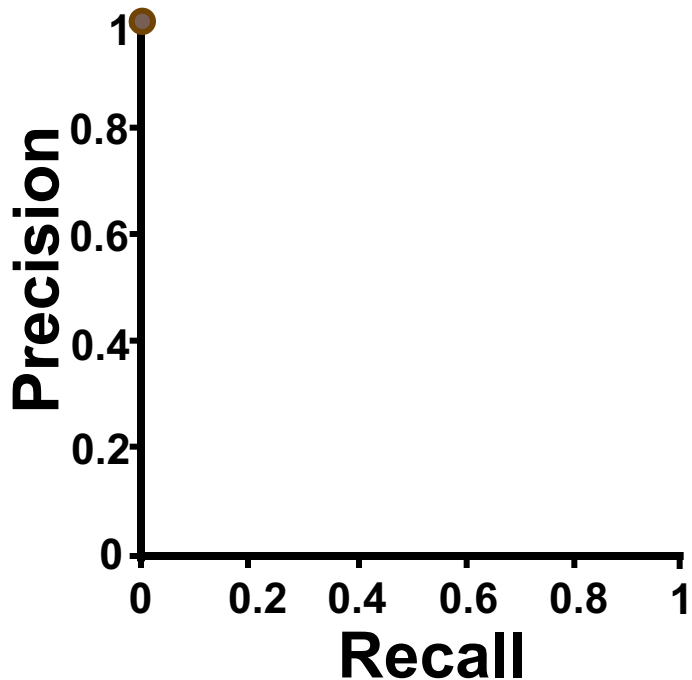


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 0 / 5
- Precision = 0 / 0



Query

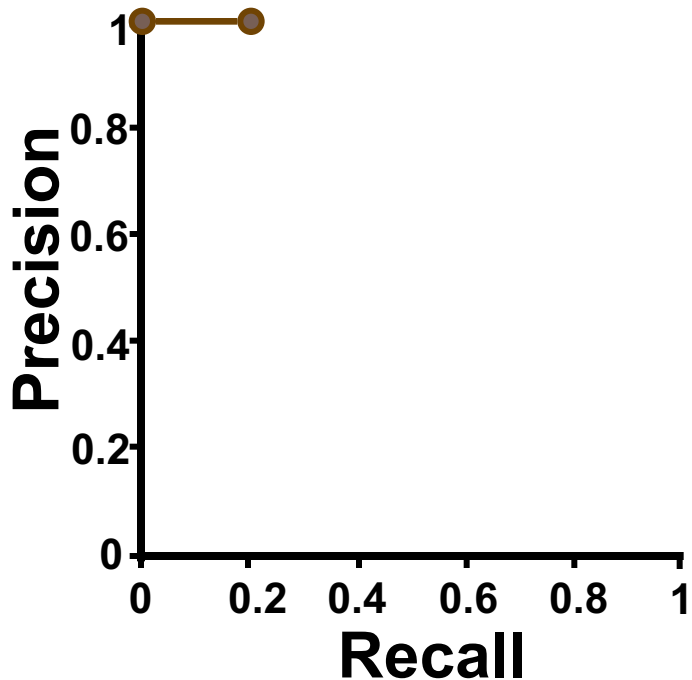


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 1 / 5
- Precision = 1 / 1



Query

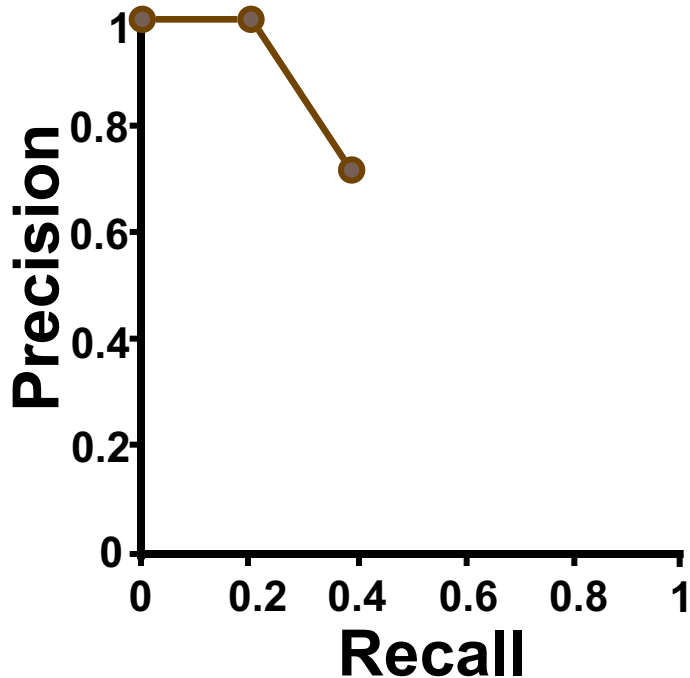


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 2 / 5
- Precision = 2 / 3



Query

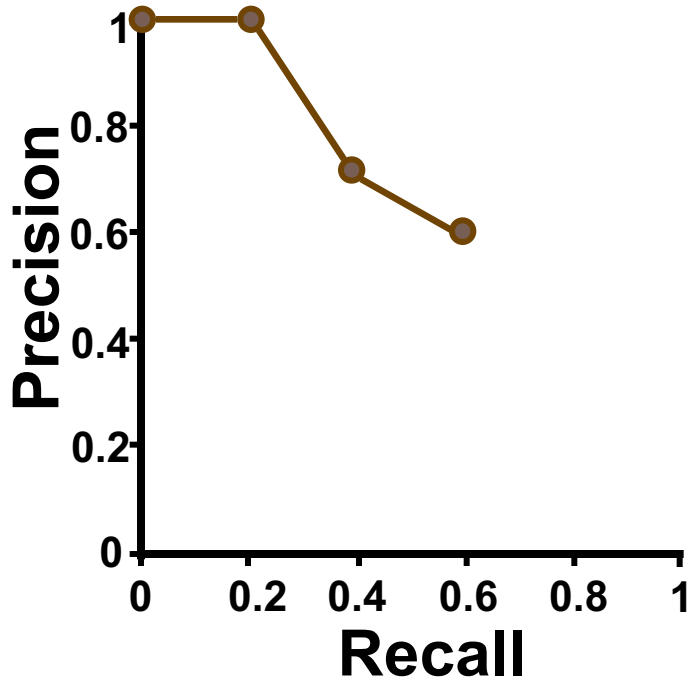


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 3 / 5
- Precision = 3 / 5



Query

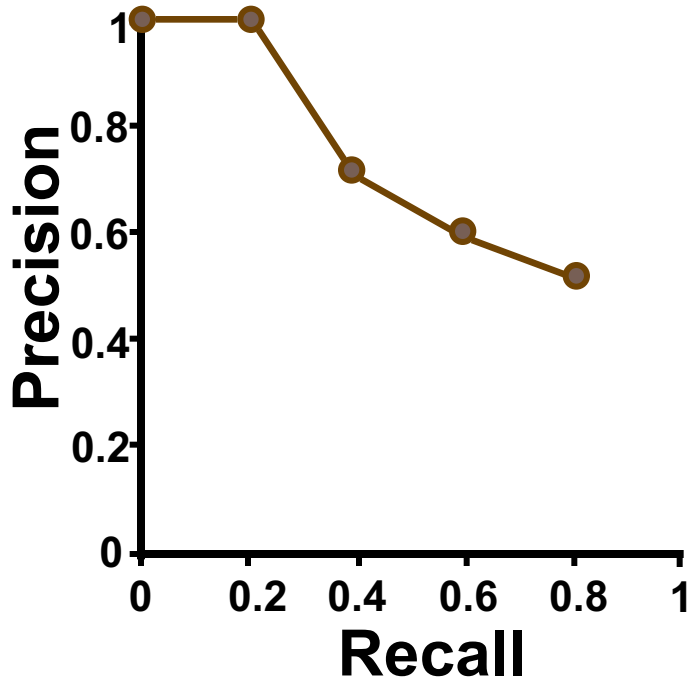


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 4 / 5
- Precision = 4 / 7



Query

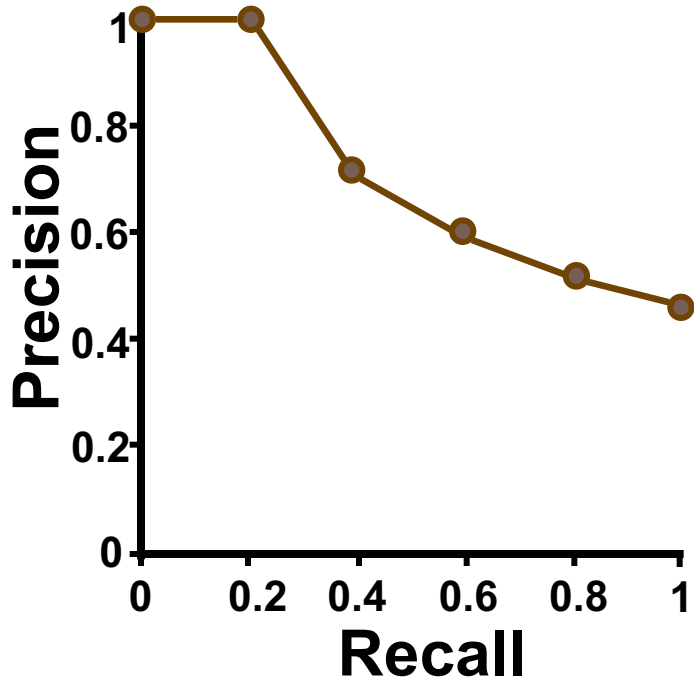


Ranked Matches

# Precision vs. Recall

## Precision-recall curves

- Recall = 5 / 5
- Precision = 5 / 9



Query



Ranked Matches





Recherche de modèles 3D utilisant le spectre de  
forme 3D

L'index de forme de Koenderink

# Spectre de courbure (Shape Index)

- Une seule valeur (Koenderink & van Doorn - 1992) :

$$I_P = \frac{2}{\pi} \arctan\left(\frac{k_P^1 + k_P^2}{k_P^1 - k_P^2}\right), \quad k_P^1 \geq k_P^2$$

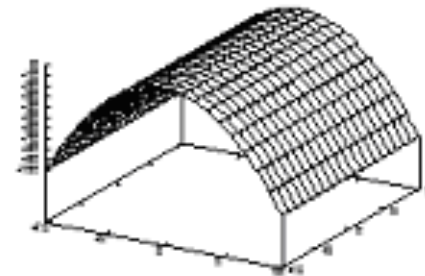
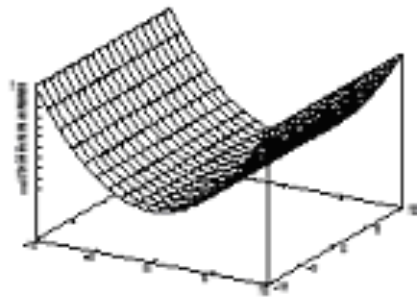
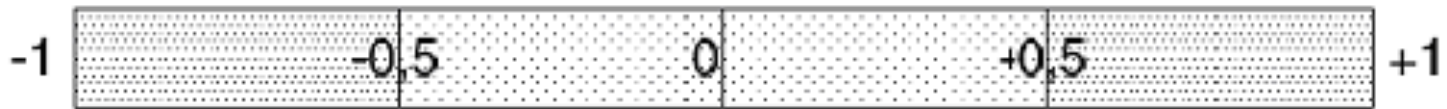
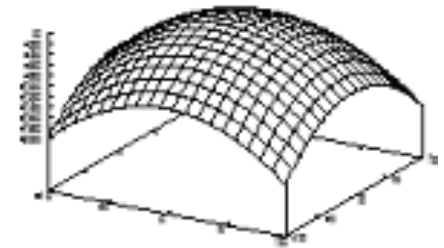
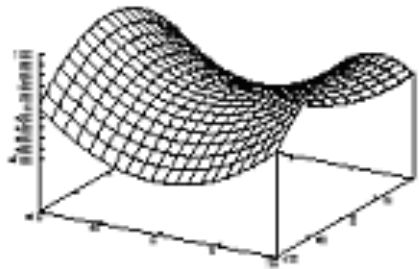
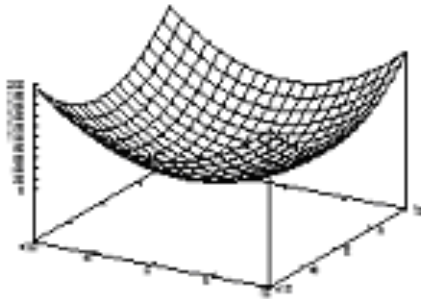
- Propriétés :

- ▣ invariante par rapport à la rotation et au facteur d'échelle
- ▣ intervalle  $[-1; +1]$
- ▣ le rapport permet de s'affranchir de la "force" des courbures
- ▣ valeurs de signes opposées = surfaces identiques mais d'orientations opposées
- ▣ calcul impossible avec :
  - $k_1 = k_2, k_1 + k_2 \neq 0$  :  $I_p = \pm 1$  selon signe de  $k_1 + k_2$
  - $k_1 = k_2 = 0$  : plan, valeur particulière attribuée à  $I_p$

# Algorithme : Histogramme de spectre de courbure

```
extraction_index_courbure (modle maill M)
dbut
  pour chaque face f du modle maill M
  faire
    determiner le voisinage 1-adjacent de f
    interpoler ce voisinage par une quadrique
    calculer les courbures principales de cette quadrique
    calculer la valeur  $I_p$  avec ces courbures
  fait
  crer l'histogramme avec les valeurs  $I_p$ 
fin.
```

# Spectre de courbure



# Paramétrisation de Monge

- Représentation implicite : la surface est l'ensemble des points  $(x,y,z)$  de l'espace vérifiant l'équation  $F(x,y,z)$ .
- Représentation paramétrique : la surface est l'image dans  $\mathbb{R}^3$  d'un sous-ensemble  $D$  de  $\mathbb{R}^2$  par une fonction  $X$  :  $X(u_1,u_2)=(x(u_1,u_2), y(u_1,u_2), z(u_1,u_2))$ .
- Représentation par graphe : la surface est l'ensemble des triplets  $(x,y,f(x,y))$ , avec  $x$  et  $y$  deux réels.

# Paramétrisation de Monge

- Une paramétrisation de Monge est une fonction différentiable  $r$ , définie d'un ouvert  $U$  de  $\mathbb{R}^2$  et à valeurs dans  $\mathbb{R}^3$ , de la forme :

$$r : U \subset \mathbb{R}^2 \rightarrow \mathbb{R}^3$$

$$\forall (u, v) \in U \quad r(u, v) = (x(u, v), y(u, v), z(u, v))^T = (u, v, z(u, v))^T$$

# Paramétrisation de Monge

$$\mathbf{x}_u = (1, 0, f_u)$$

$$\mathbf{x}_v = (0, 1, f_v)$$

$$\mathbf{x}_{uv} = (0, 0, f_{uv})$$

$$\mathbf{x}_{uu} = (0, 0, f_{uu})$$

$$\mathbf{x}_{vv} = (0, 0, f_{vv})$$

$$\mathbf{x}_{vu} = (0, 0, f_{vu})$$

# Les formes fondamentales de la paramétrisation de Monge

$$\mathbf{I} = \begin{pmatrix} 1 + \mathbf{f}_x^2 & \mathbf{f}_x \mathbf{f}_y \\ \mathbf{f}_x \mathbf{f}_y & 1 + \mathbf{f}_y^2 \end{pmatrix} \quad \mathbf{II} = \frac{1}{\sqrt{1 + \mathbf{f}_x^2 + \mathbf{f}_y^2}} \begin{pmatrix} \mathbf{f}_{xx} & \mathbf{f}_{xy} \\ \mathbf{f}_{xy} & \mathbf{f}_{yy} \end{pmatrix}$$

$$\mathbf{N} = -\frac{(\mathbf{f}_x, \mathbf{f}_y, -1)^t}{\sqrt{1 + \mathbf{f}_x^2 + \mathbf{f}_y^2}}$$



# Approximation par une quadrique

Soit une surface tridimensionnelle dont les points sont définis par  $(x, y, f(x, y))$  où  $f$  est un polynôme du second degré :

$$f(x, y) = a_0x^2 + a_1y^2 + a_2xy + a_3x + a_4y + a_5$$

$$\{a_i \in \mathbb{R}\}_{i=0}^5$$

La surface est alors appelée une *quadrique*

# Approximation par une quadrique

En notant  $a = (a_0, a_1, a_2, a_3, a_4, a_5)^t$  et  $b(x, y) = (x^2, y^2, xy, x, y, 1)^t$ , l'équation précédente peut se noter sous forme matricielle :

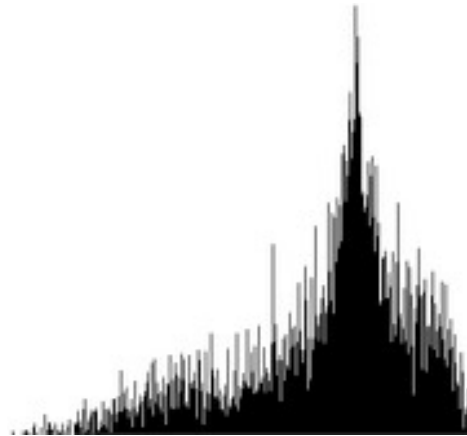
$$f(x, y) = a^t \cdot b(x, y)$$

$$a = \left( \sum_{i=1}^{i=N} b(x_i, y_i) b^t(x_i, y_i) \right)^{-1} \left( \sum_{i=1}^{i=N} z_i b(x_i, y_i) \right)$$

# Histogramme du spectre de courbure

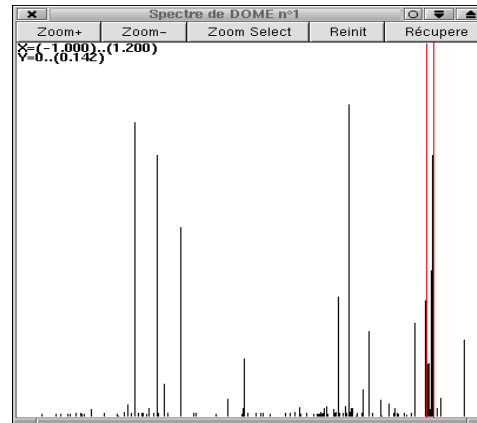
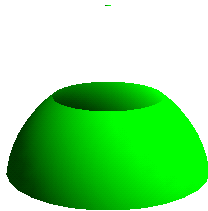
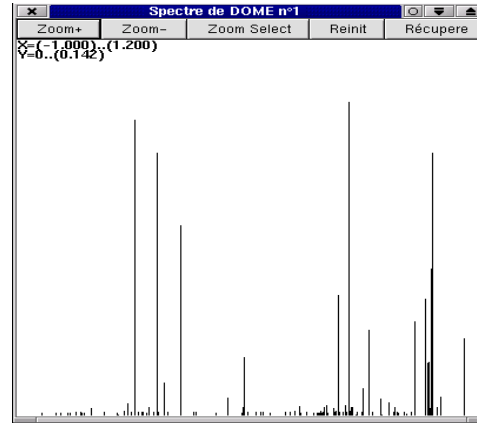


**5804 faces**



**courbures**

# Exemple



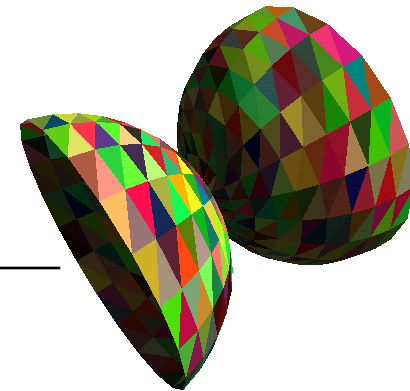
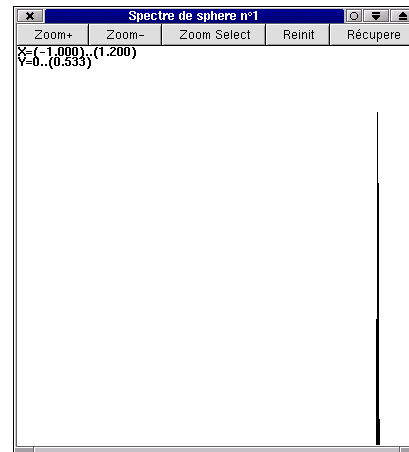
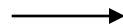
# Comparaison

- Pour comparer les spectres, on utilise une méthode commune
- Calcul de la distance de Minkowski d'ordre 1 :

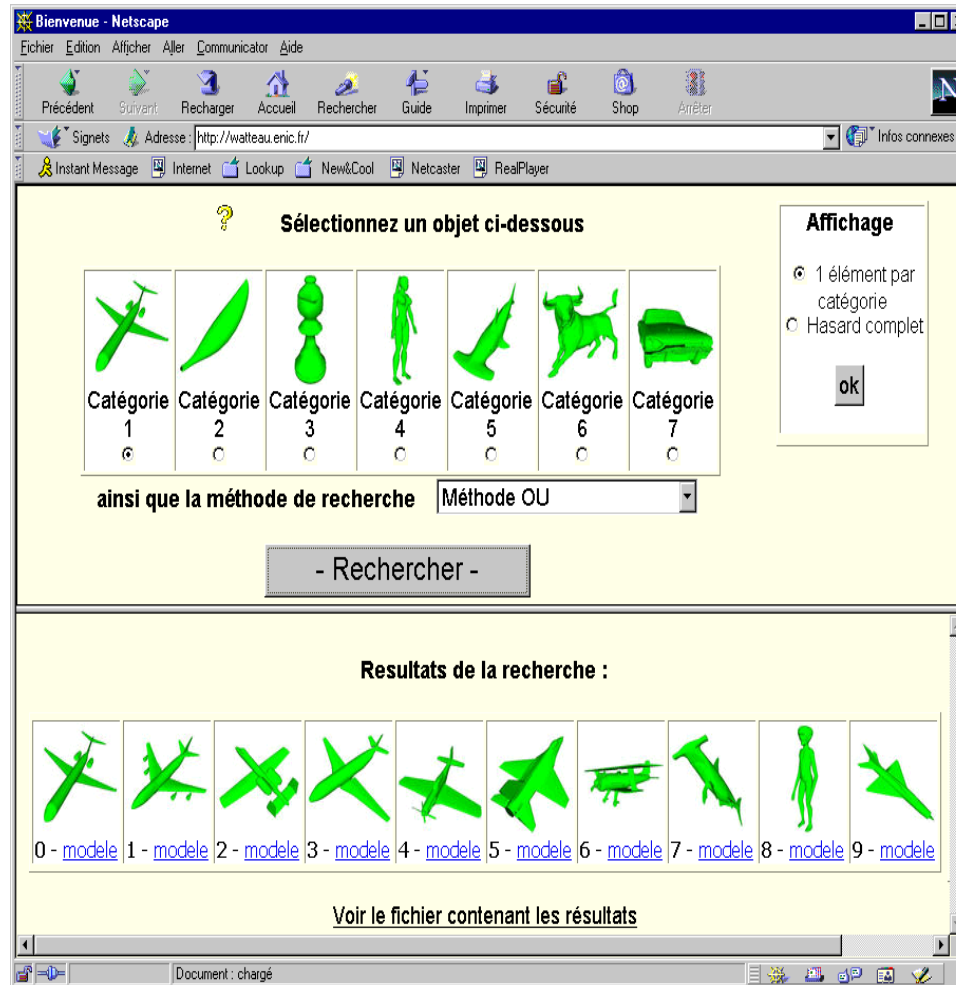
$$d(f_1, f_2) = \int |f_1(x) - f_2(x)|.dx$$

# Problèmes de l'approche locale

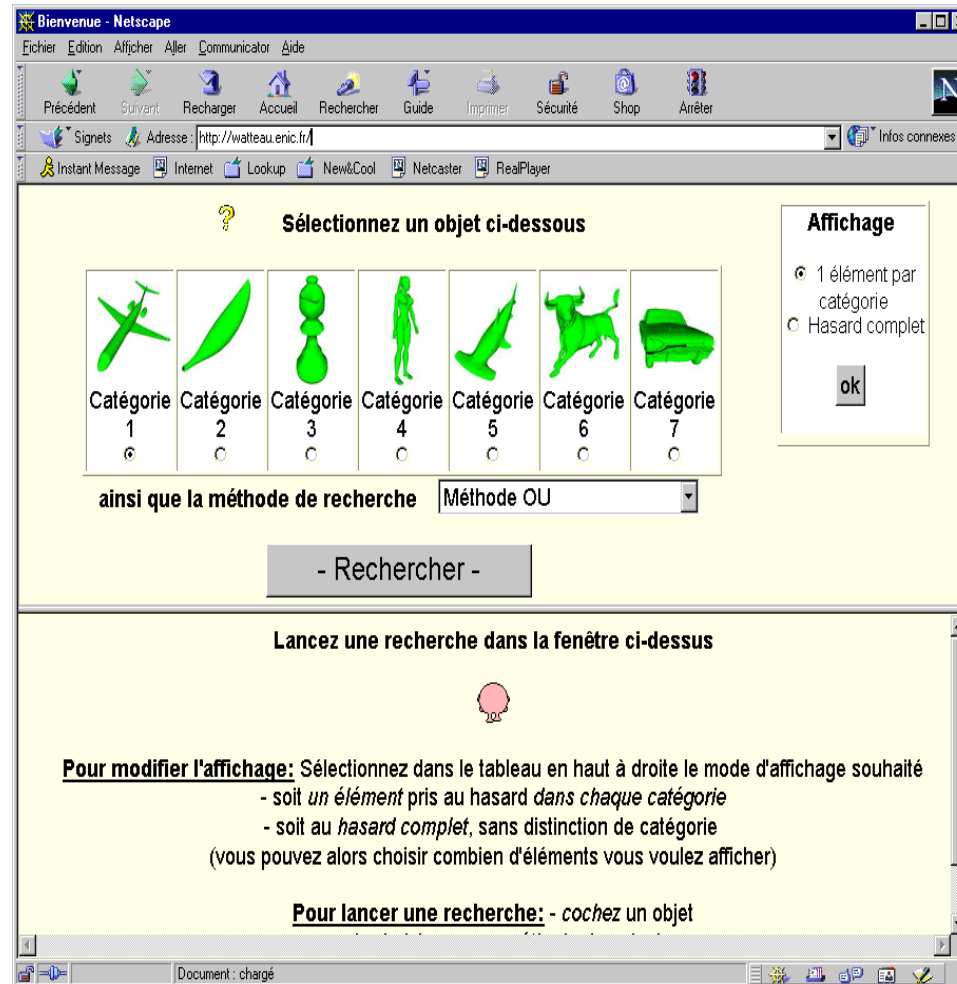
- Voisinage
- Perte importante d'information



# Interface du moteur



# Interface du moteur







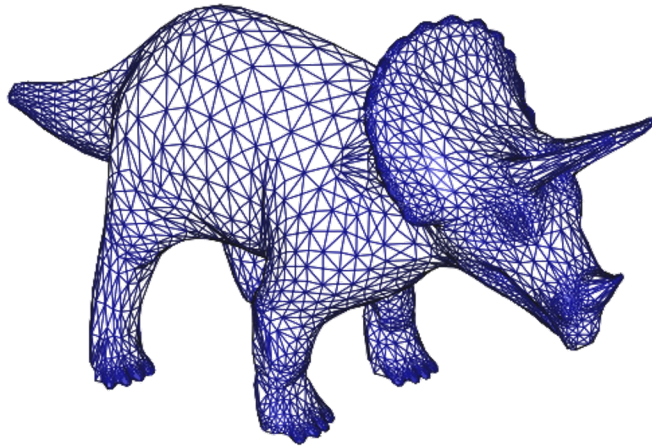
Recherche de modèles 3D basée sur la  
distribution de distance D2

[R. Osada et al. SMI 2001]

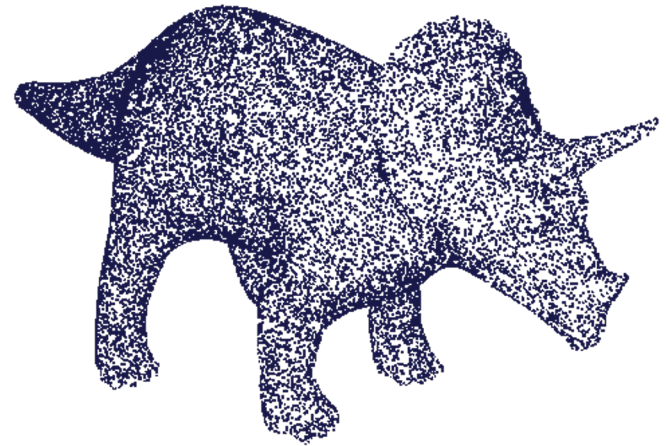
# D2 Distribution de distance [R. Osada et al. SMI 2001]

L'idée clef 1 : en considérant les points la méthode évite les problèmes du genre, de connectivité, etc ..

**Triangulated Model**



**Point Set**



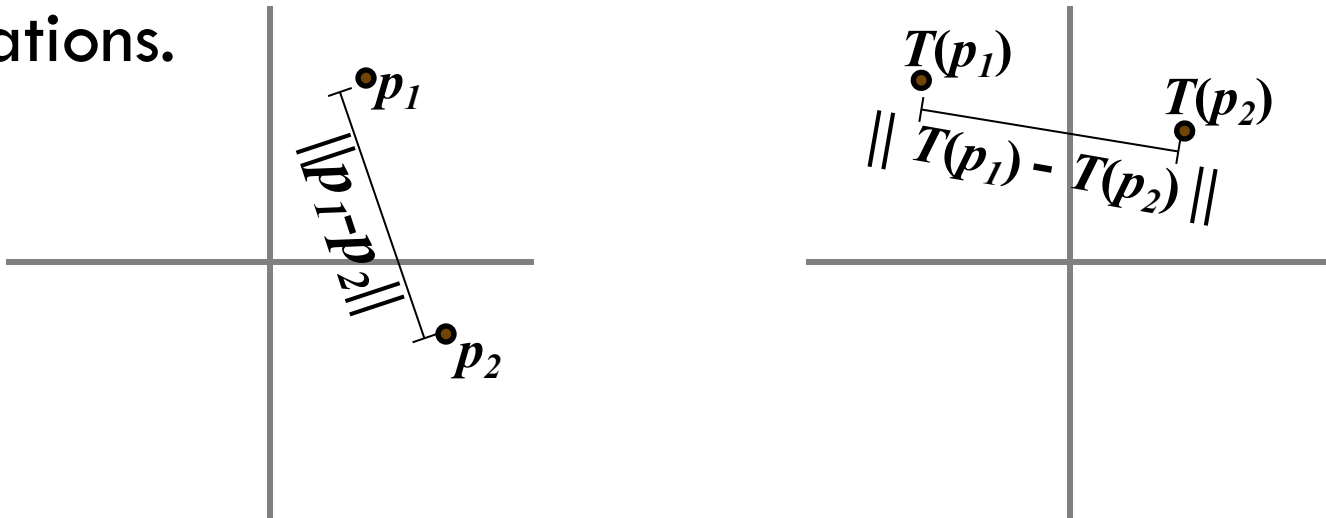
# D2 Distribution de distance

L'idée clef 2 :

La distance entre 2 points ne changent pas si les deux points subissent une translation ou une rotation :

$$\|p_1 - p_2\| = \|T(p_1) - T(p_2)\|$$

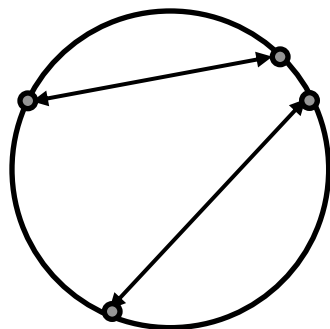
Pour toutes  $T$  combinaisons de translations et de rotations.



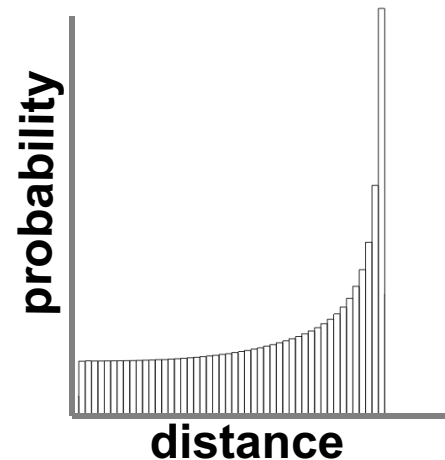
# D2 Distribution de distance

Définition: Pour un ensemble de points  $P$ , et la distance  $d$ , la valeur de la distribution D2 en  $d$  est le nombre dont la distance entre deux points est  $d$  :

$$D2_P(d) = \frac{|\{p, q \in P \text{ s.t. } \|p - q\| = d\}|}{|P|^2}$$



Model



D2

# D2 Distribution de distance

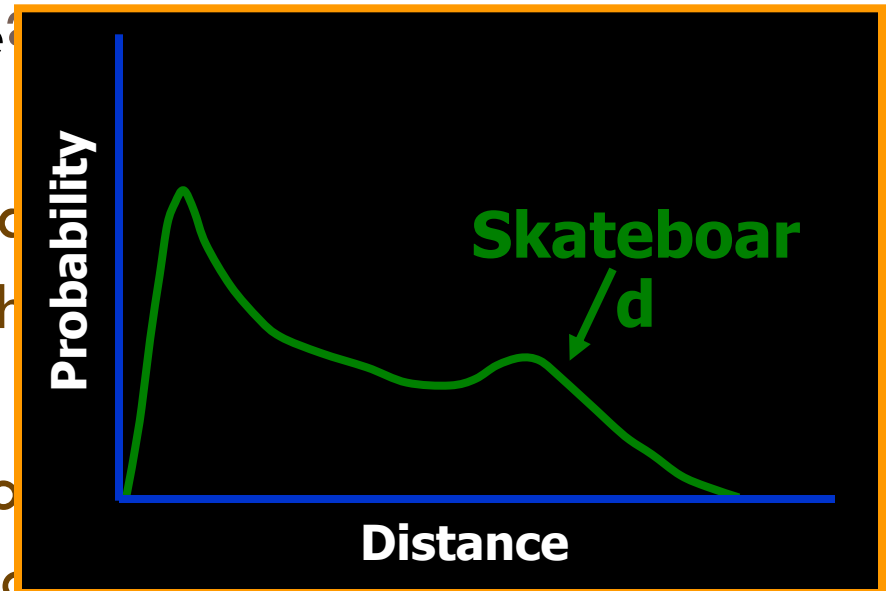
## □ Propriétés

- Concis pour le stockage?
- Rapide à calculer?
- Invariant aux transformations géométriques?
- Efficacité de la recherche?
- Robuste au bruit?
- Pas très sensible à la topologie?
- Robuste aux dégénérescences?
- Invariant aux déformations?
- Pouvoir Discriminant?

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**512 bytes (64 values)**

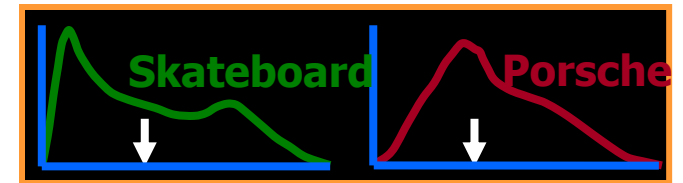
**0.5 seconds ( $10^6$  samples)**

# D2 Distribution de distance

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- ✓ Translation
- ✓ Rotation
- ✓ Mirror
- ✓ Scale (w/ normalization)

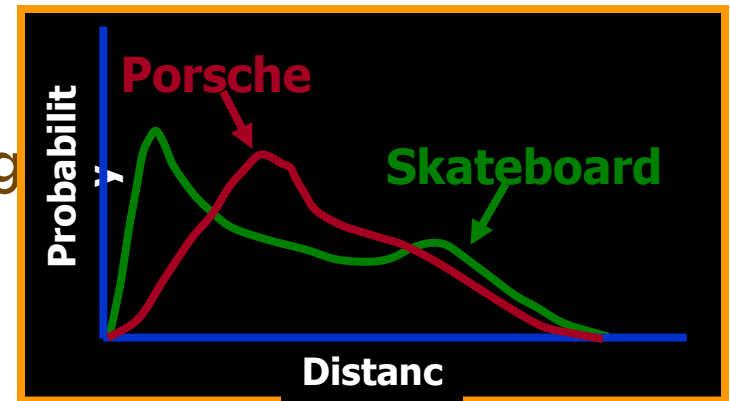


**Les moyennes normalisées**

# D2 Distribution de distance

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# D2 Distribution de distance

## □ Propriétés

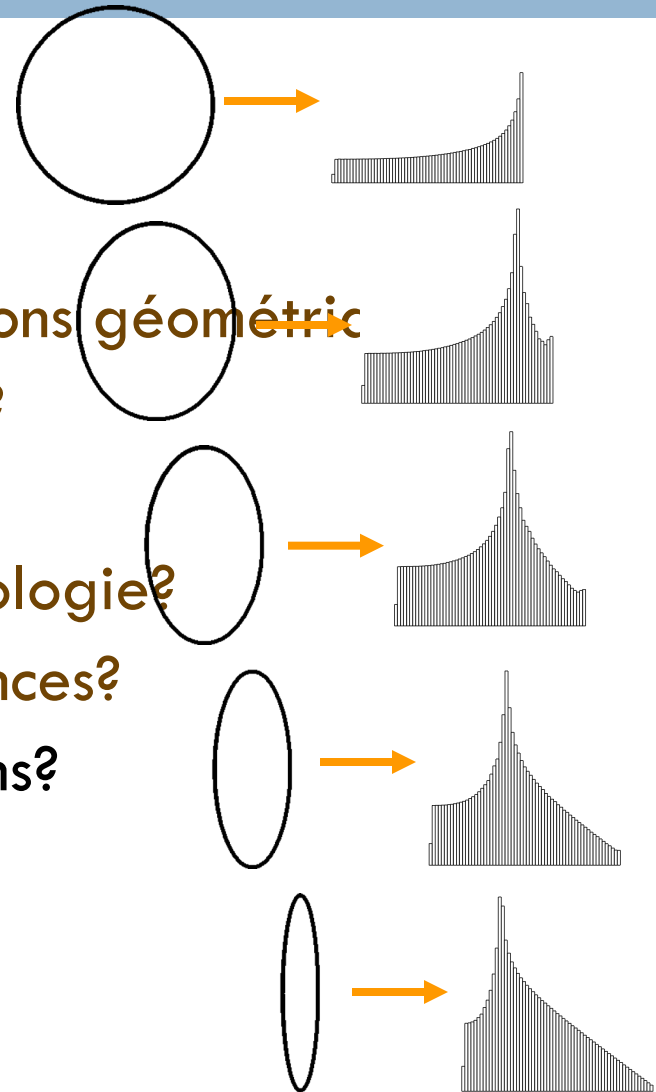
- ✓ Concis pour le stockage?
- ✓ Rapide à calculer?
- ✓ Invariant aux transformations
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# D2 Distribution de distance

## □ Propriétés

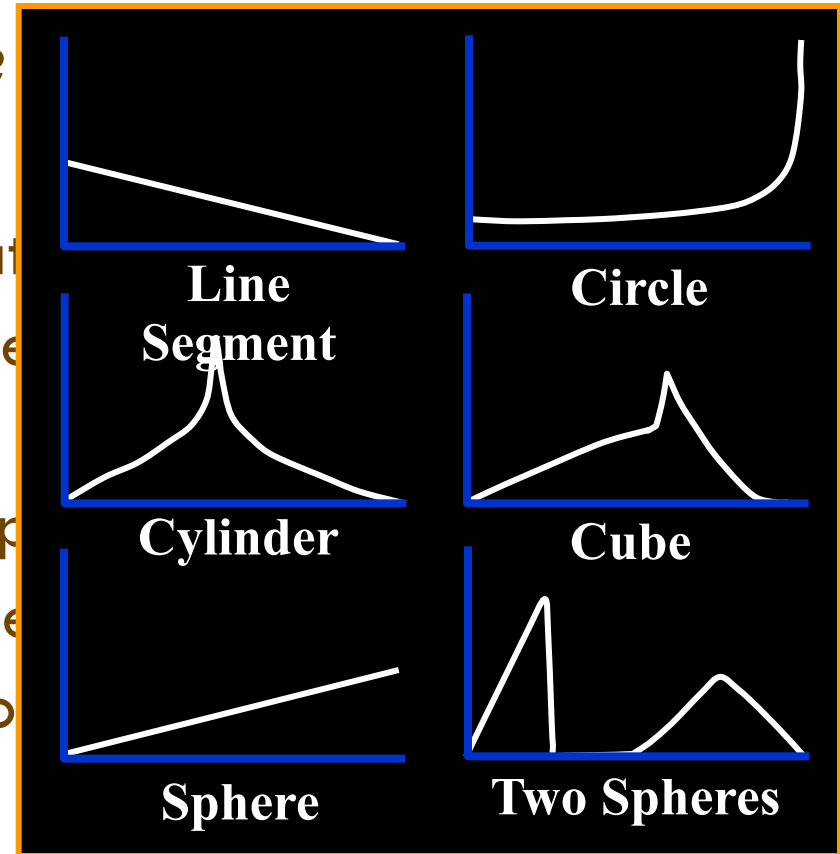
- ✓ Concis pour le stockage?
- ✓ Rapide à calculer?
- ✓ Invariant aux transformations géométric
- ✓ Efficacité de la recherche?
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- ✓ Pas très sensible à la topologie?
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# D2 Distribution de distance

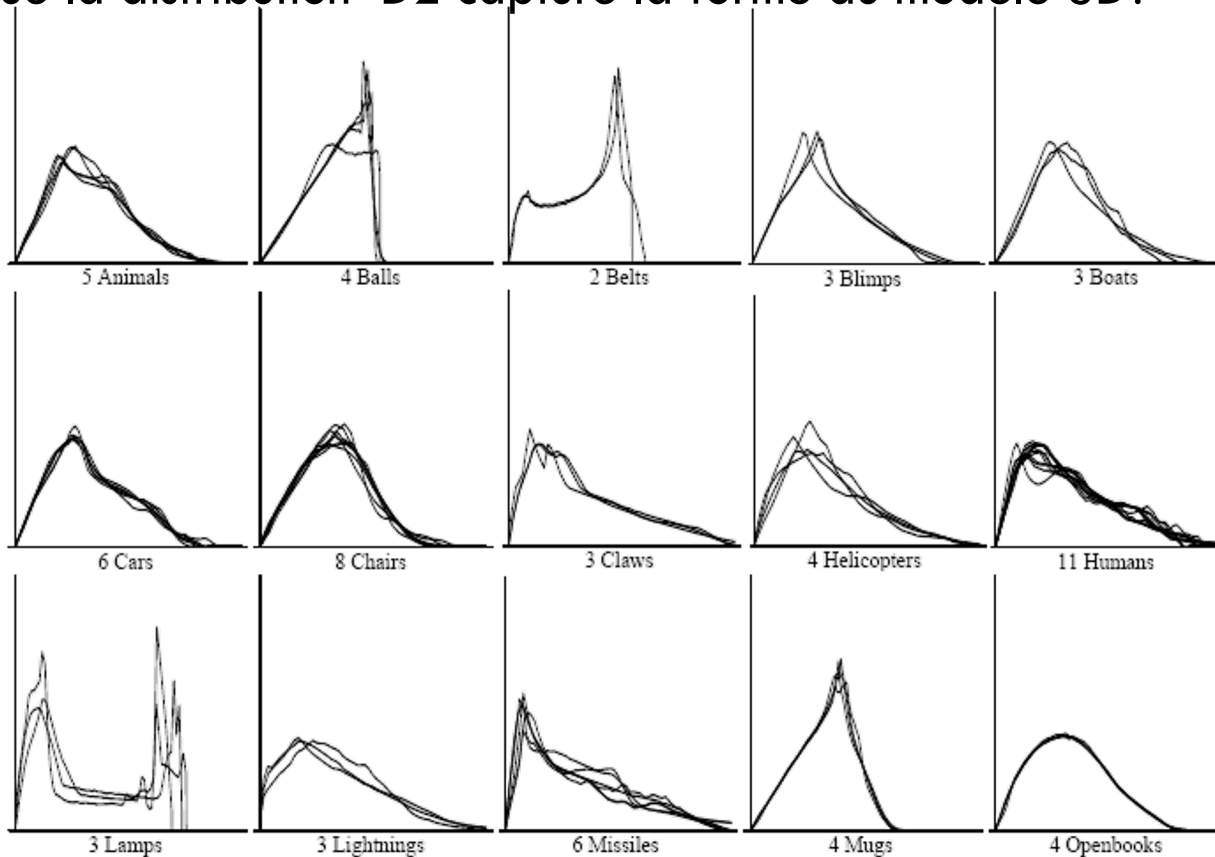
## □ Propriétés

- ✓ Concis pour le stockage?
  - ✓ Rapide à calculer?
  - ✓ Invariant aux transformations
  - ✓ Efficacité de la recherche
  - ✓ Robuste au bruit?
  - ✓ Pas très sensible à la topologie
  - ✓ Robuste aux dégénérescences
  - × Invariant aux déformations
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# D2 Distribution de distance

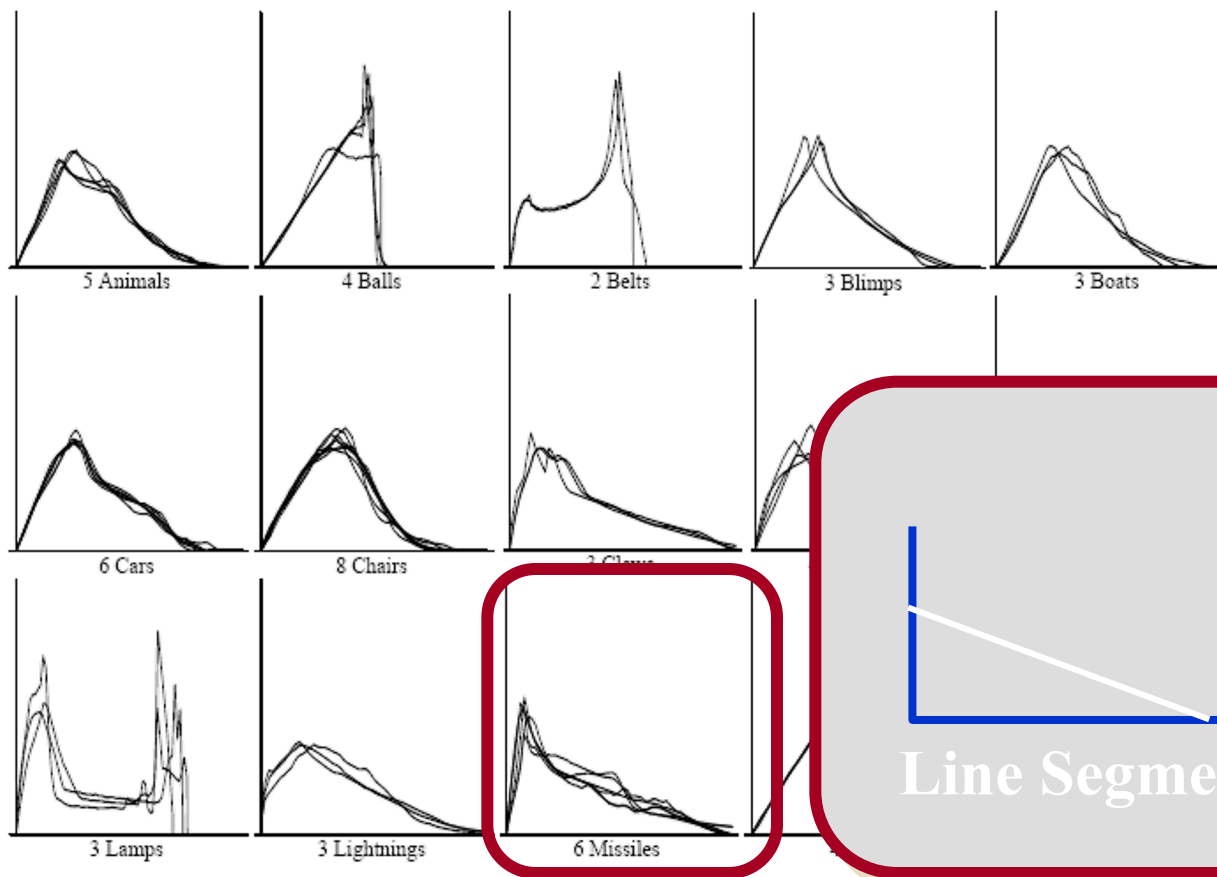
Est ce que la distribution D2 capture la forme du modèle 3D?



**La distribution D2 pour 15 classes d'objects**

# D2 Distribution de distance

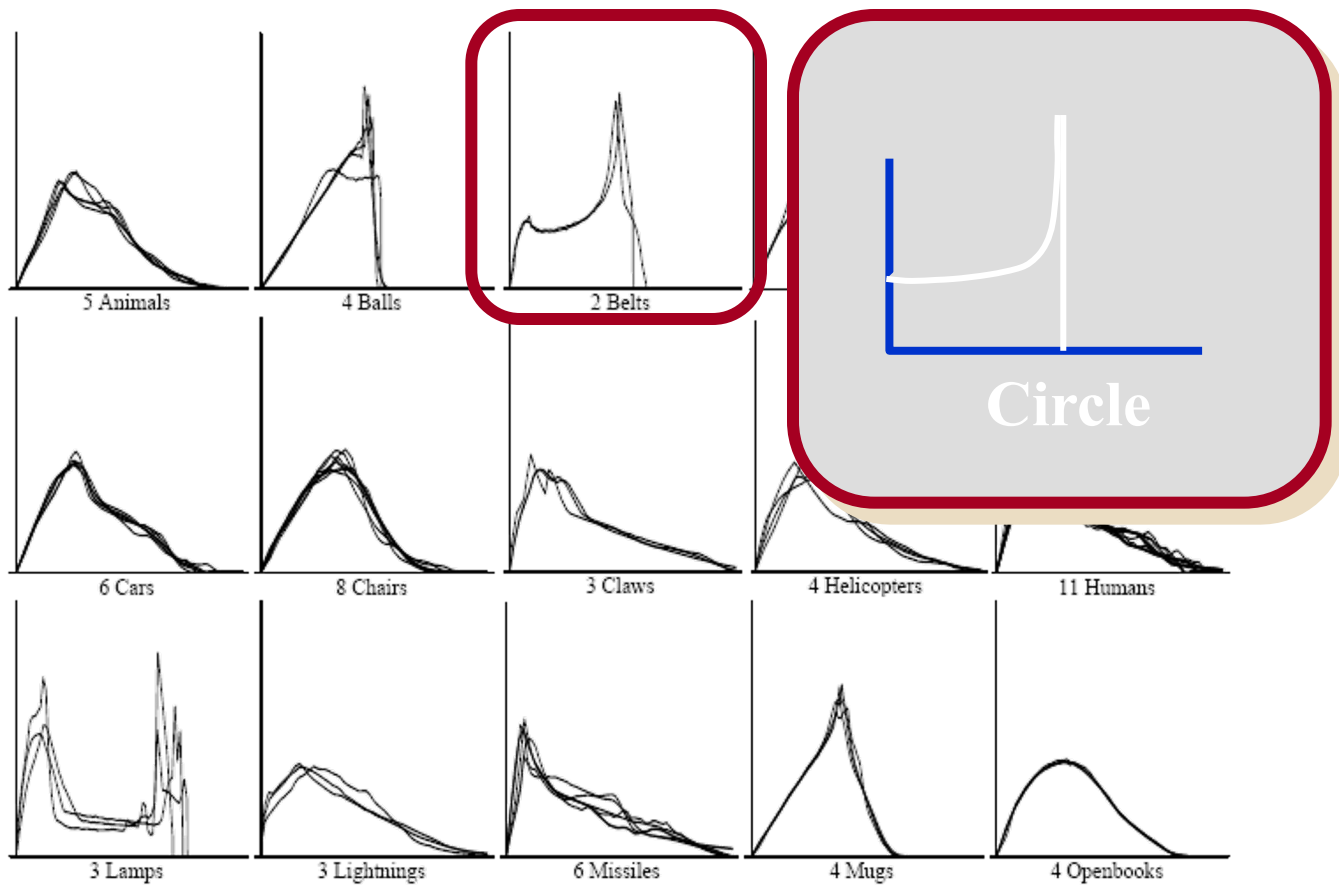
Est ce que la distribution D2 capture la forme du modèle 3D?



**D2 shape distributions pour 15 classes d'objets**

# D2 Distribution de distance Résultats

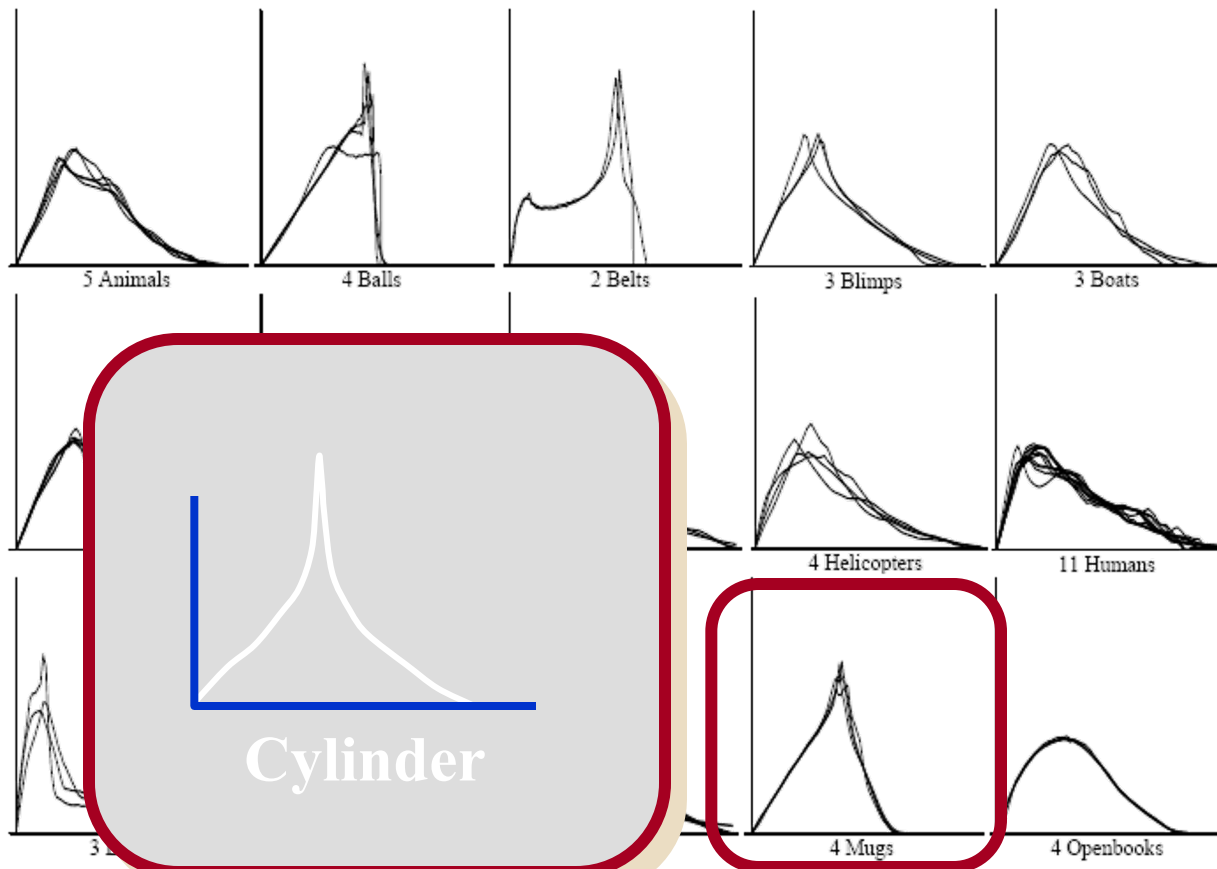
Est ce que la distribution D2 capture la forme du modèle 3D?



**D2 shape distributions for 15 classes of objects**

# D2 Distribution de distance Résultats

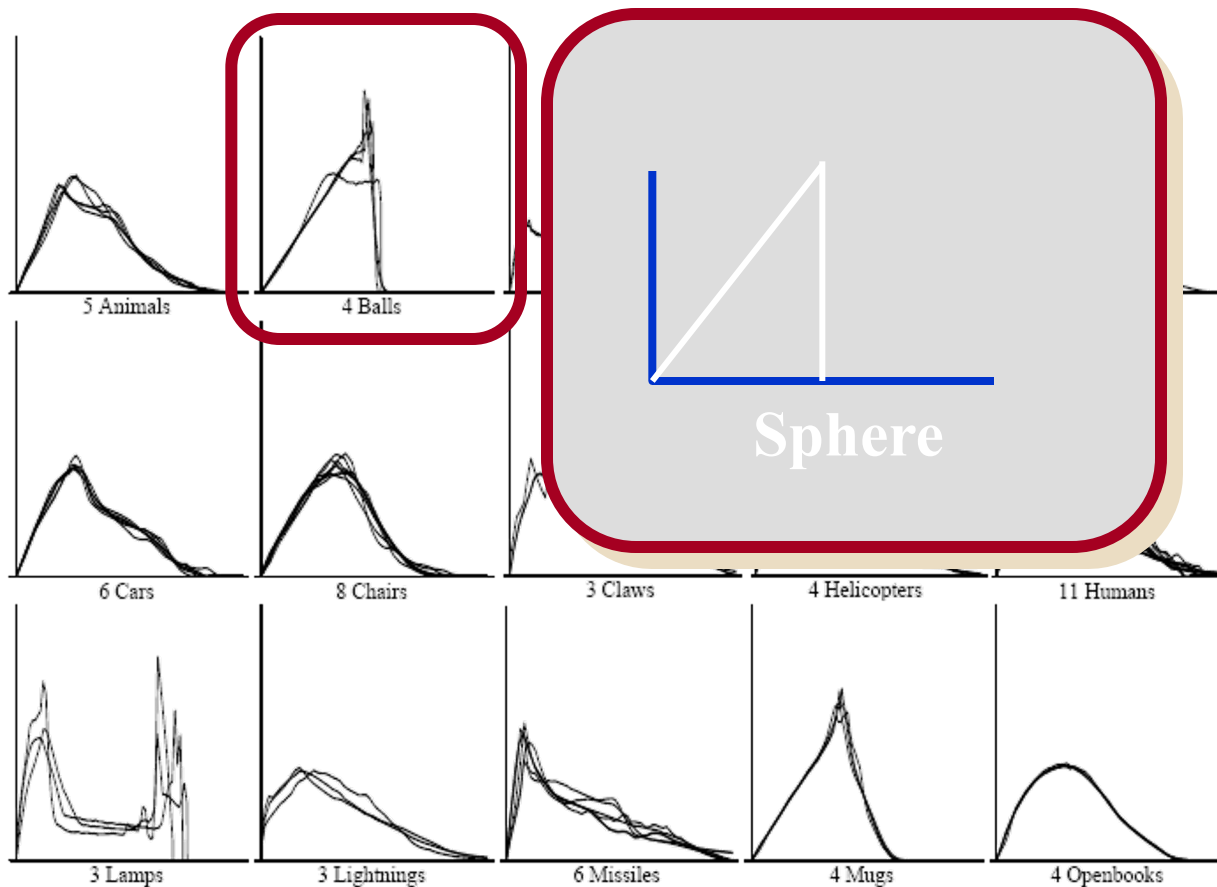
Est ce que la distribution D2 capture la forme du modèle 3D?



**D2 shape distributions for 15 classes of objects**

# D2 Distribution de distance Résultats

Est ce que la distribution D2 capture la forme du modèle 3D?

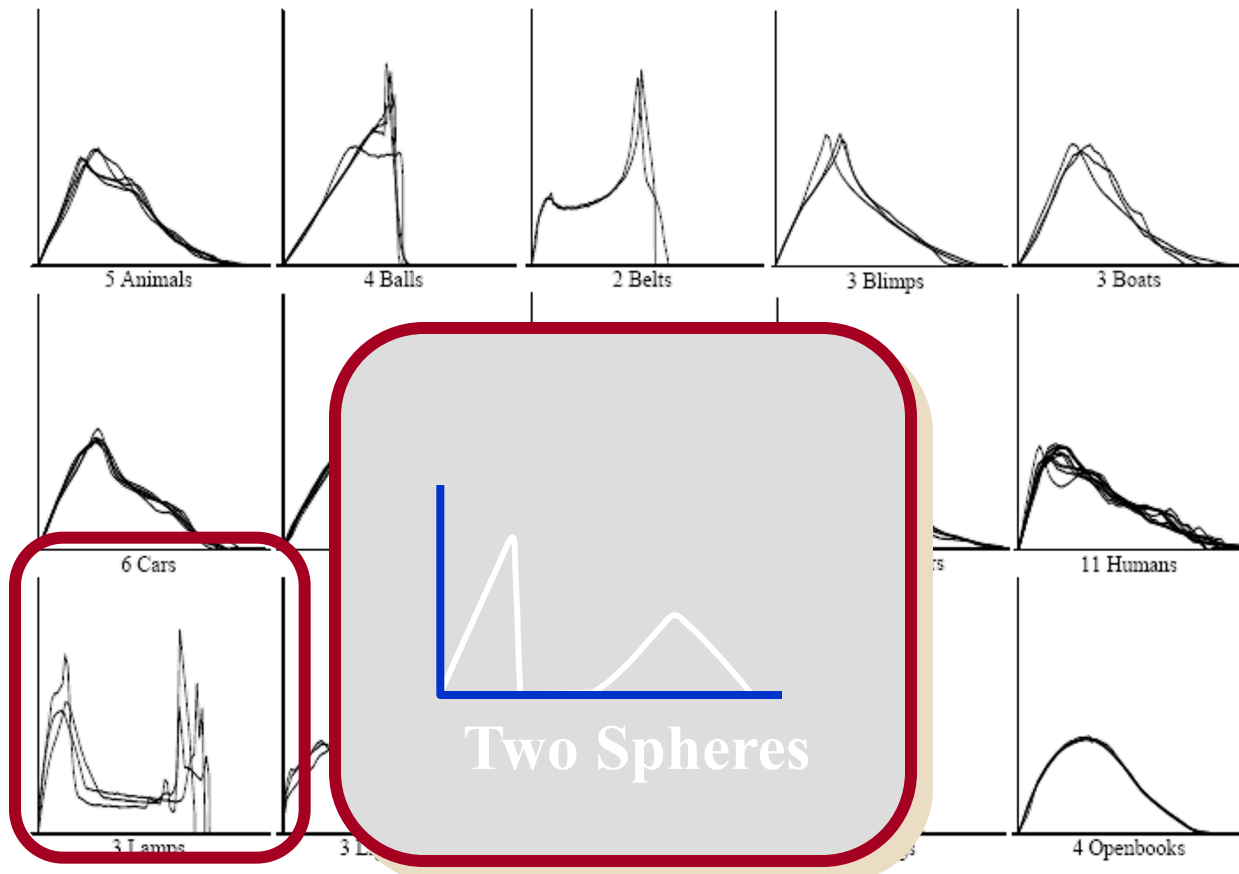


**D2 shape distributions for 15 classes of objects**



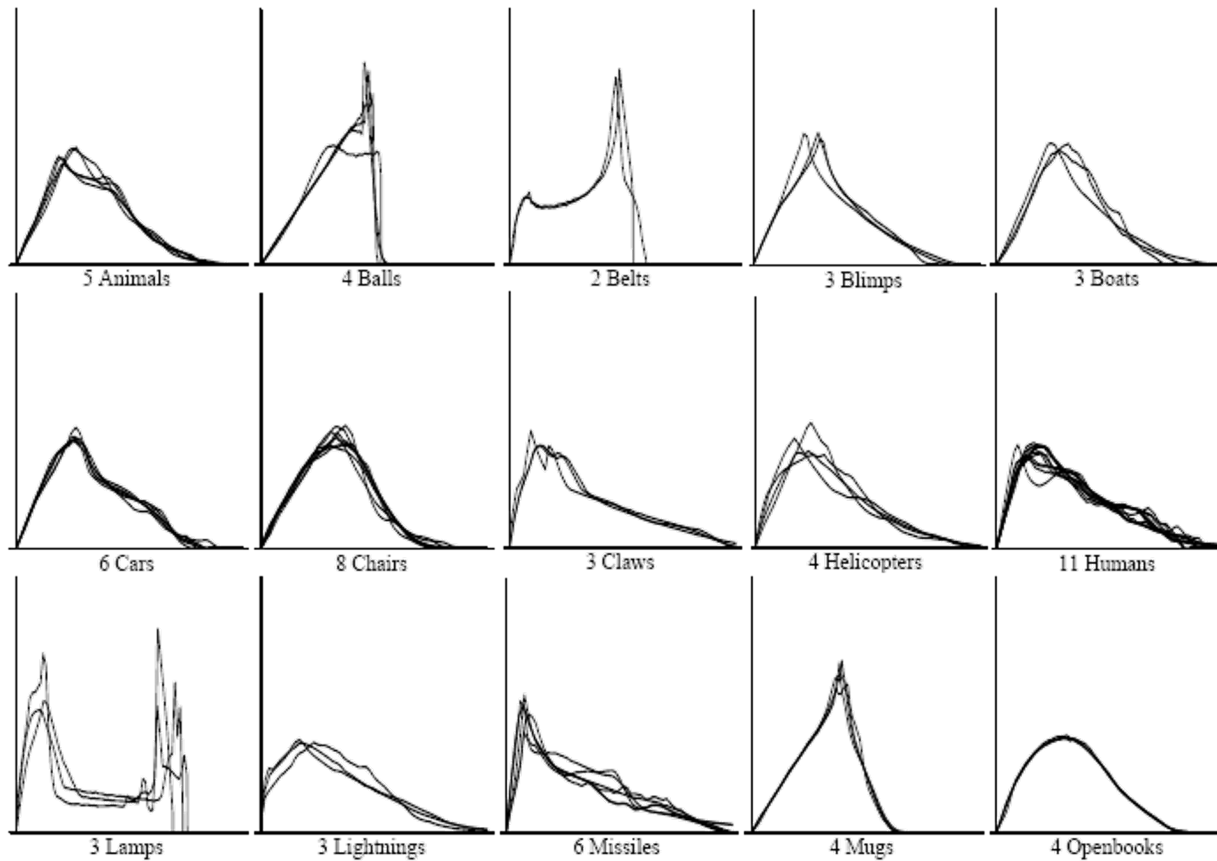
# D2 Distribution de distance Résultats

Est ce que la distribution D2 capture la forme du modèle 3D?



**D2 shape distributions for 15 classes of objects**

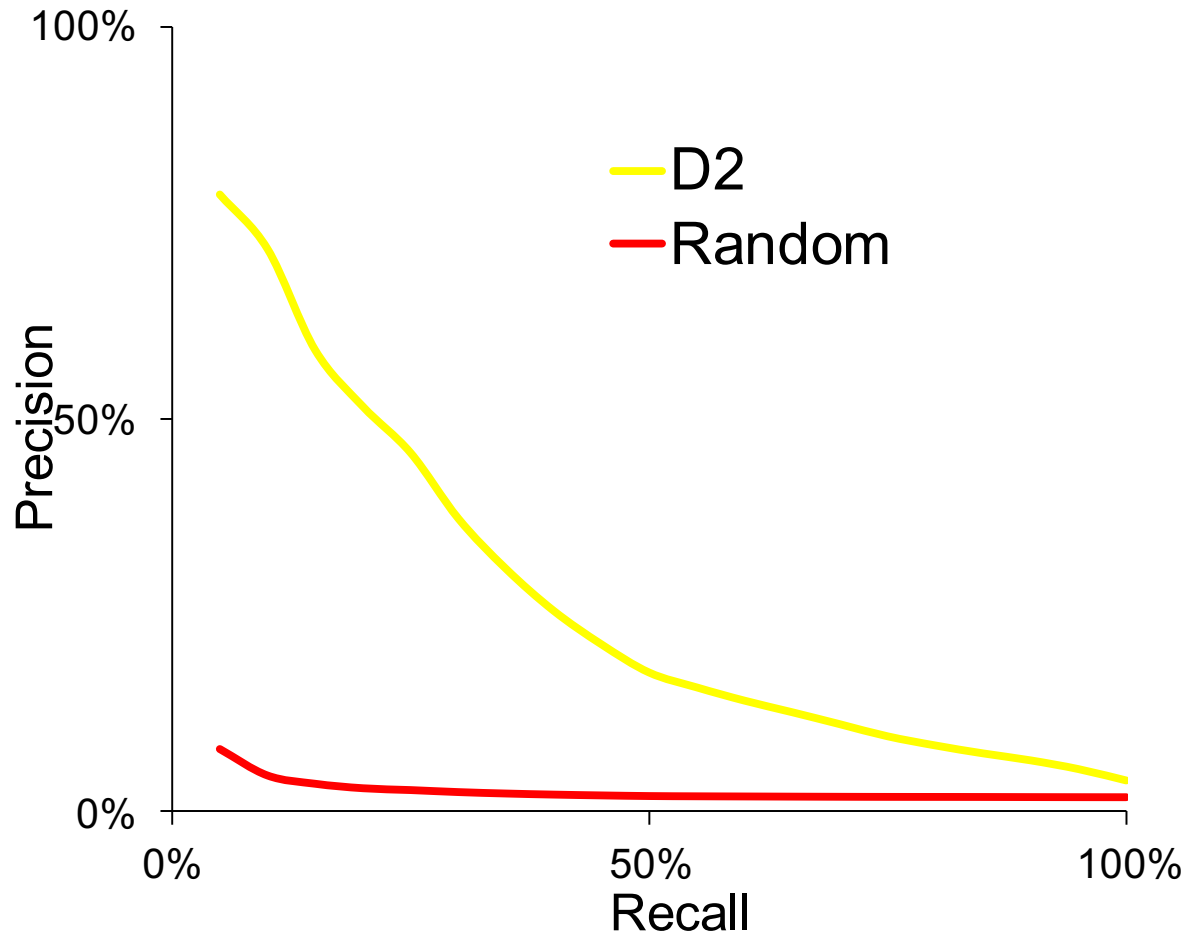
# D2 Distribution de distance Résultats



**D2 shape distributions for 15 classes of objects**

# D2 Distribution de distance

## Precision vs. recall on Princeton Benchmark



# Conclusion

---

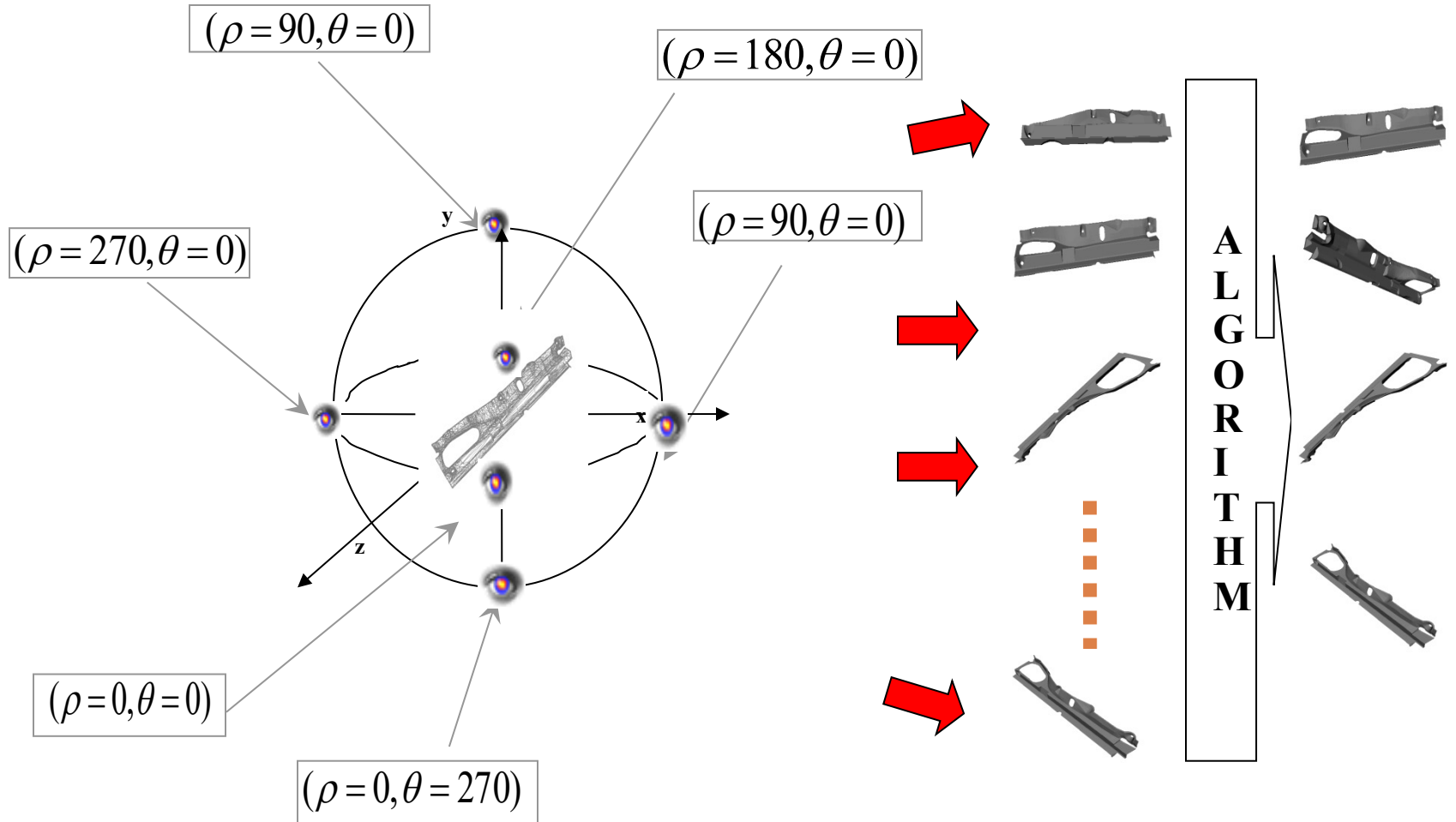
- Les descripteur statistiques représentent la géométrie du modèle
- Permettent de comparer des modèles 3D rigides.
- Mauvais pour comparer des objets déformables.
- Mauvais pour comparer des parties de deux modèles 3D.



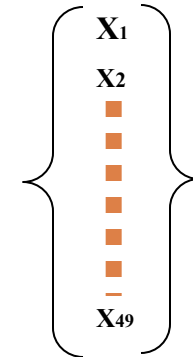
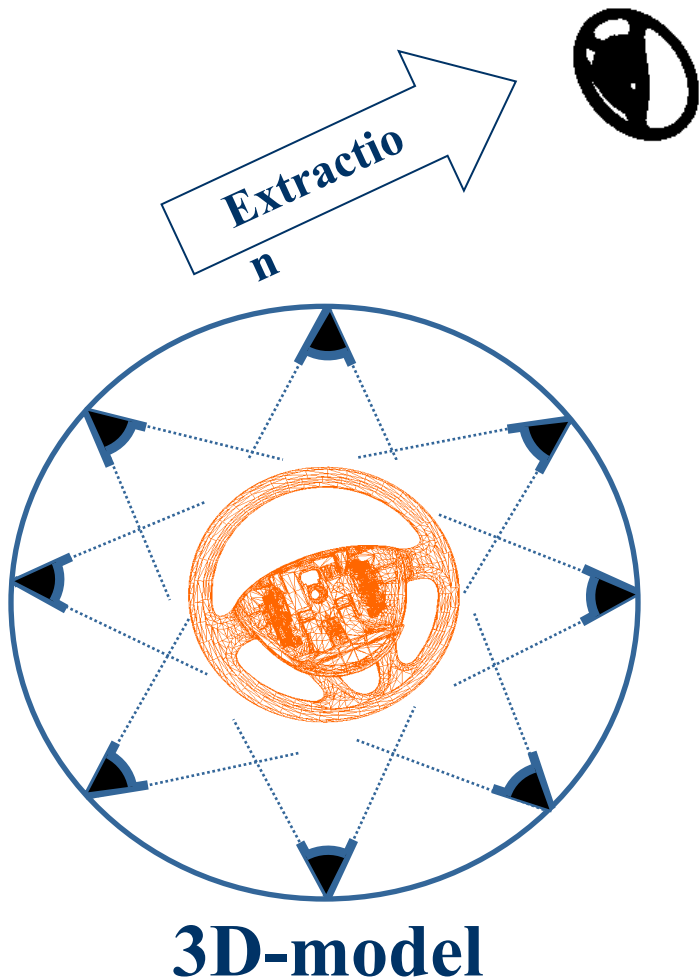
## Approches vues

T.Filali Ansary, M. Daoudi, J-P Vandeborre, A  
Bayesian 3D Search Engine using Adaptive Views  
Clustering, IEEE Transactions On Multimedia

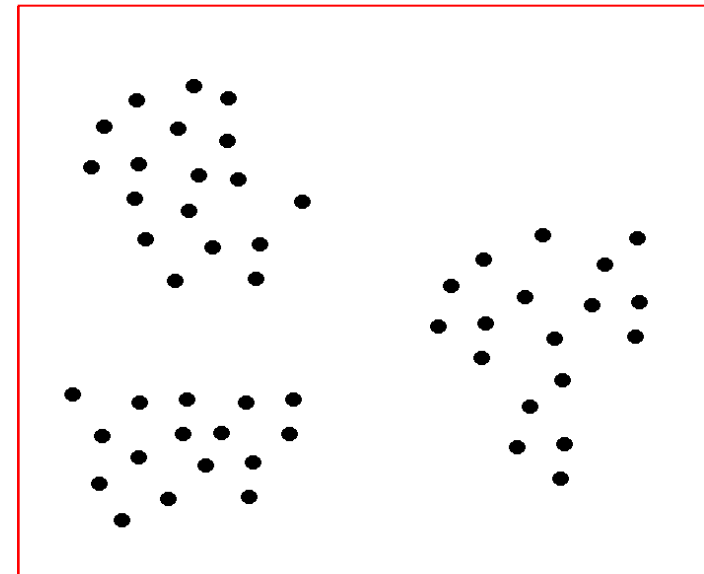
# Notre approche



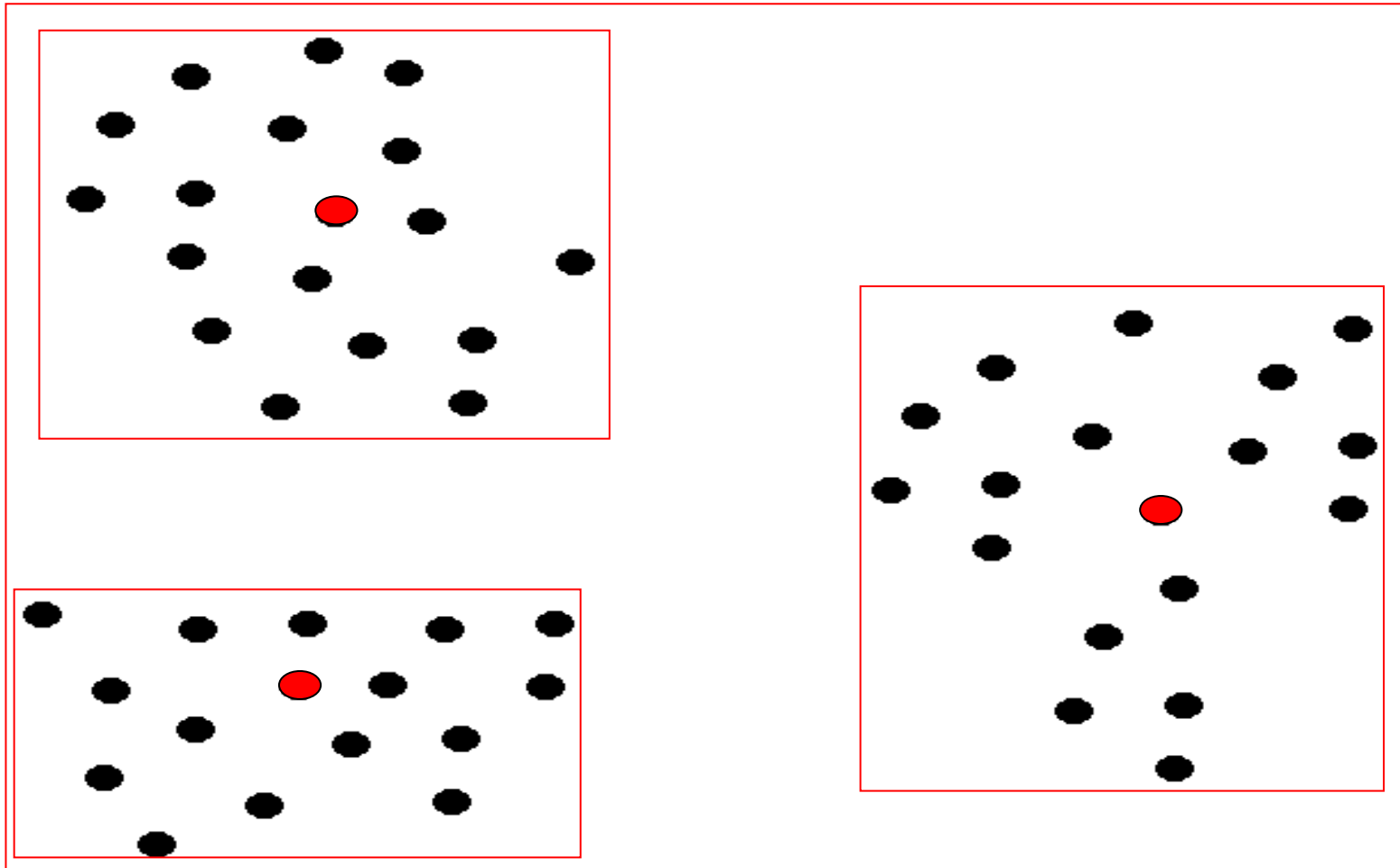
# Initial Set of Views



**Zernike Moments**



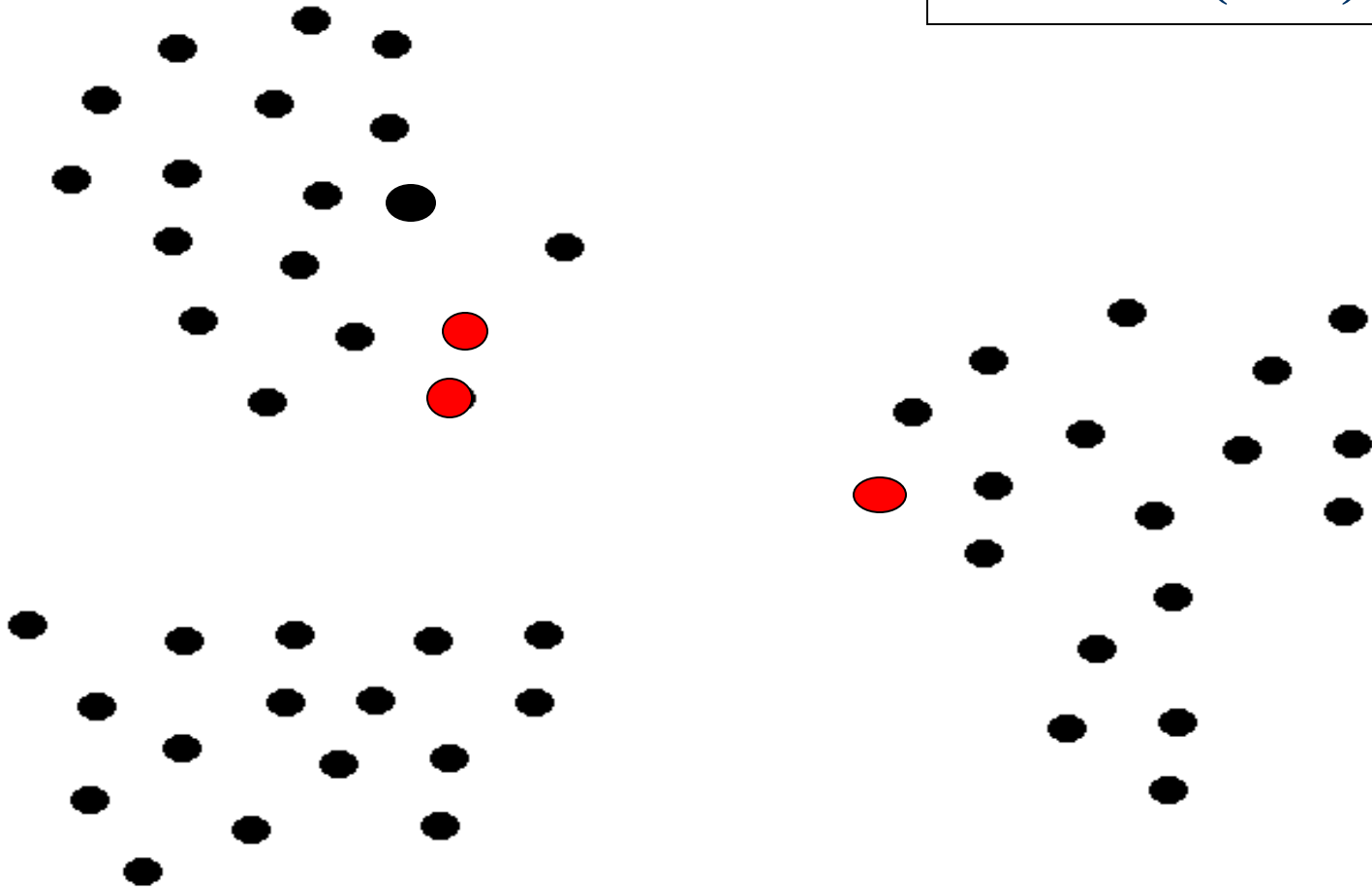
# Adaptive Views Clustering





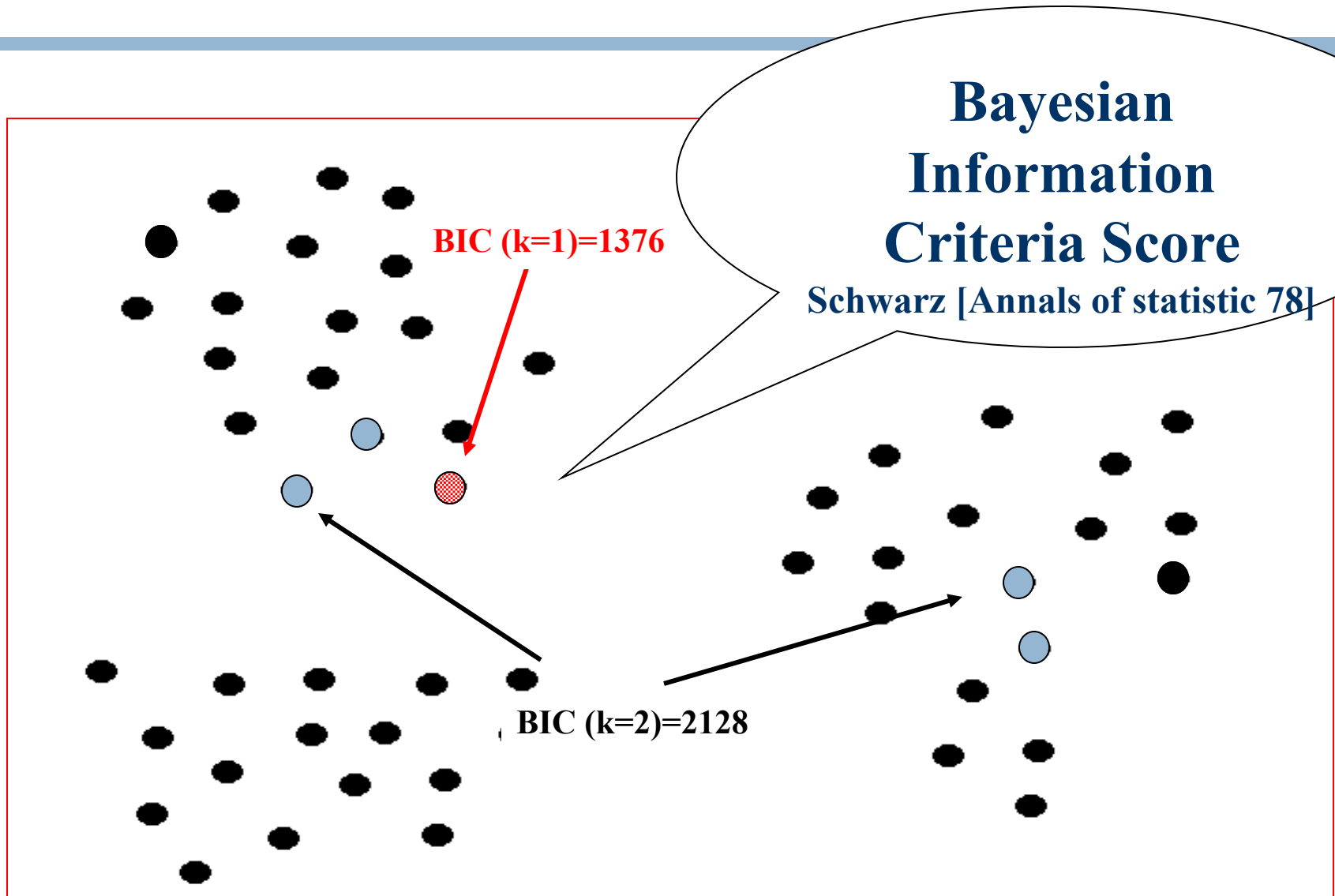
# Adaptive Views Clustering

**K-means (K=1)**



# Adaptive Views Clustering

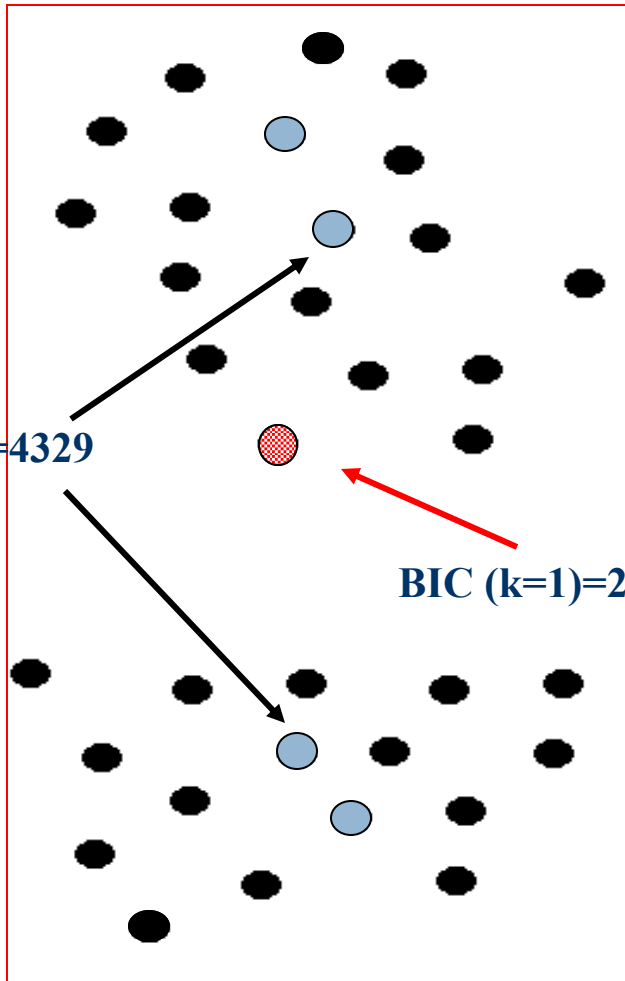
X-Means, D. Pelleg [ICML00]



# Adaptive Views Clustering

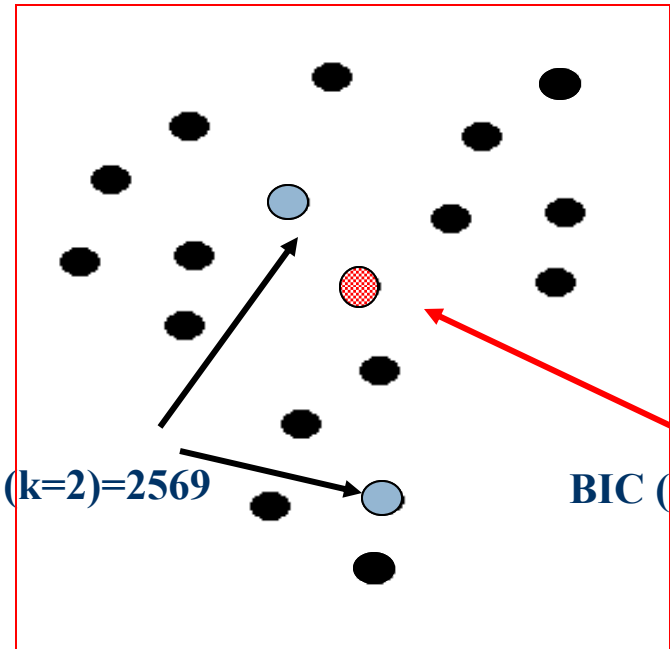
## Local K-means (K=2)

BIC (k=2)=4329



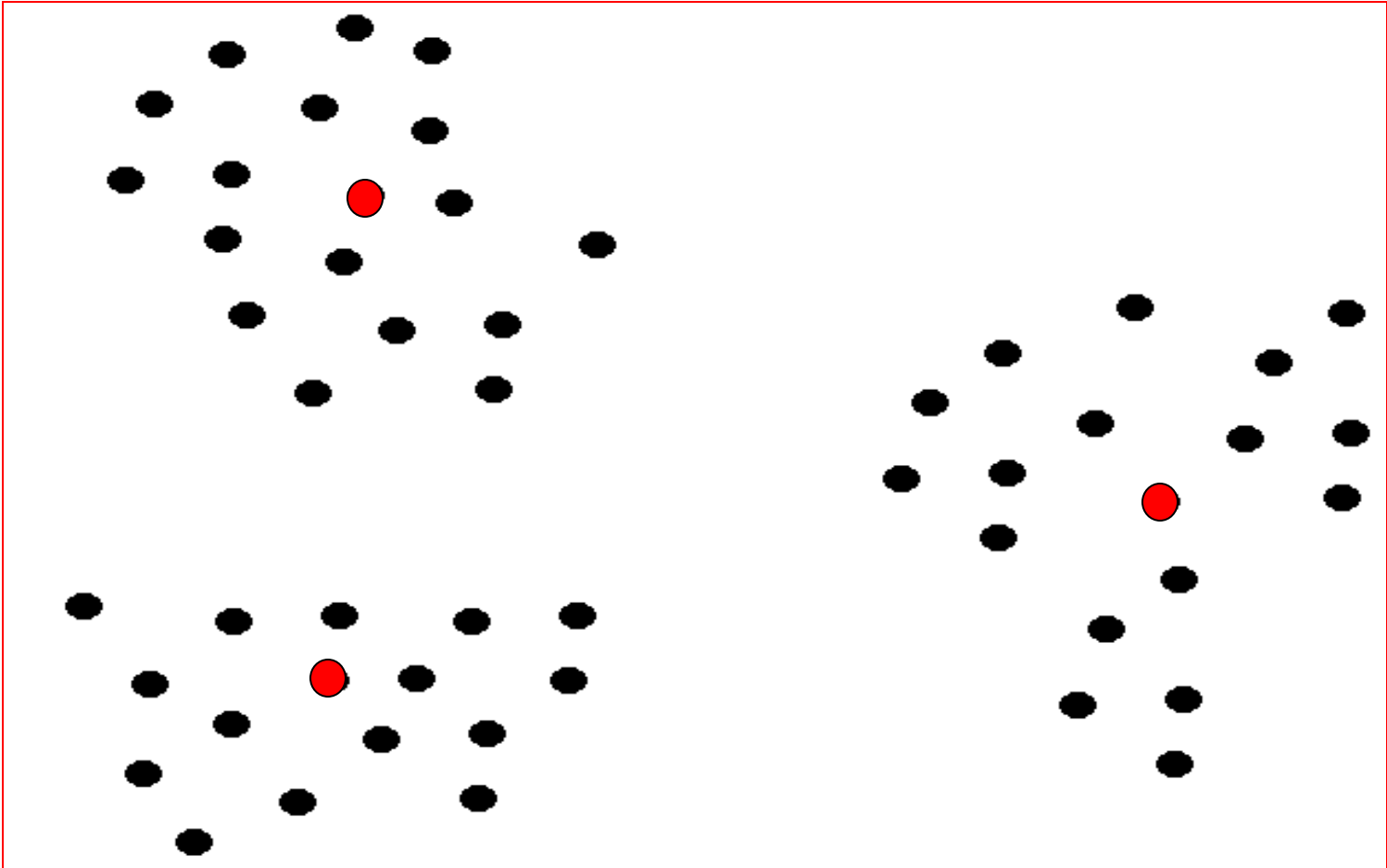
BIC (k=1)=2137

BIC (k=2)=2569

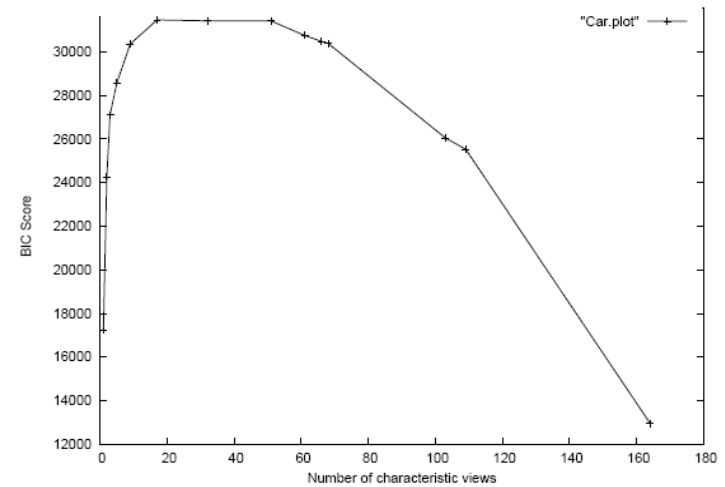
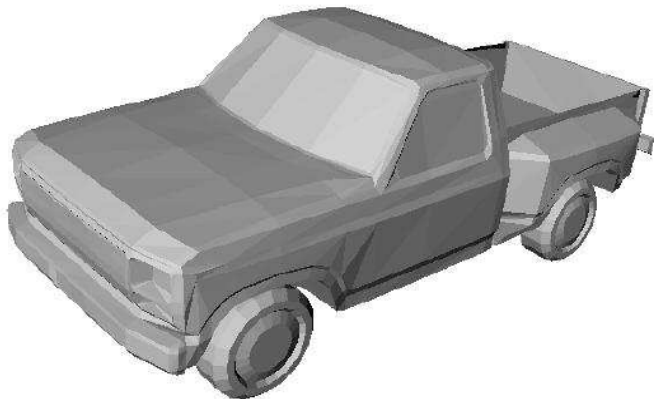
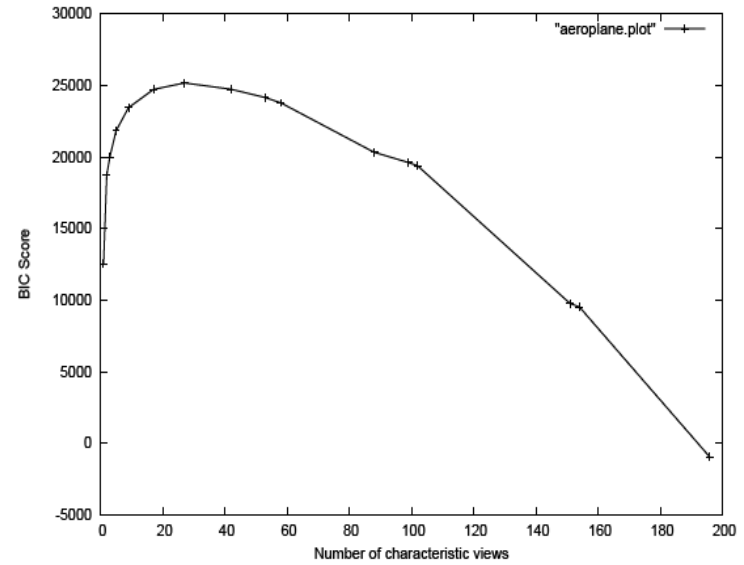


BIC (k=1)=381

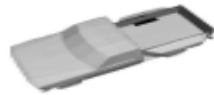
# Adaptive Views Clustering



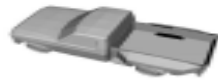
# BIC Score Curve



# Vues Caractéristiques



(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)



(i)



(j)



(k)



(l)



(m)



(n)



(o)



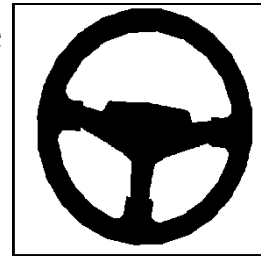
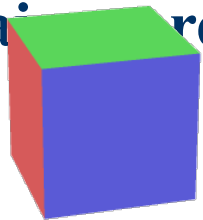
(p)



(q)

# Formulation Probabiliste de l'Indexation

- All the 3D-models do not have the same **probability** to be observed.
- All views do not have equal importance, there are views that contain more information on the object than the others.



- Considering a 3D-request-model  $Q$ , we want to find the model which is the closest to the query  $Q$ . The  $P(M_i|Q)$  is the one that has the highest probability

# Formulation Probabiliste à l'Indexation

Using **Bayesian** theorem we obtain:

$$P(M_i|Q) = \sum_{k=1}^K \text{Max}_j \left( \frac{P(h_j^k | V_{M_i}^j, M_i) P(V_{M_i}^j | M_i) P(M_i)}{\sum_{i=1}^N \sum_{j=1}^{\hat{v}} P(h_j^k | V_{M_i}^j, M_i) P(V_{M_i}^j | M_i) P(M_i)} \right) P(I^k | Q).$$

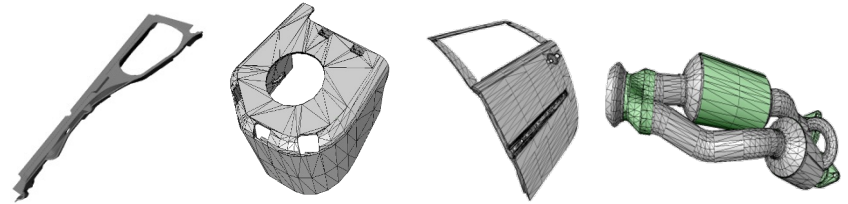
- $P(M_i)$  **the probability to observe the 3D-mod** $M_i$  .
- $P(V_{M_i}^j | M_i)$  **the probability to observe the characteristic view  $j$  of the model** $M_i$  .



# Protocole Experimentale

## Dataset:

- **SEMANTIC-3D Database:**
  - 5000 3D-models
  - 758 classified models
  - 76 classes
- **Princeton Shape Benchmark:**
  - 1814 3D-models
  - 161 classes



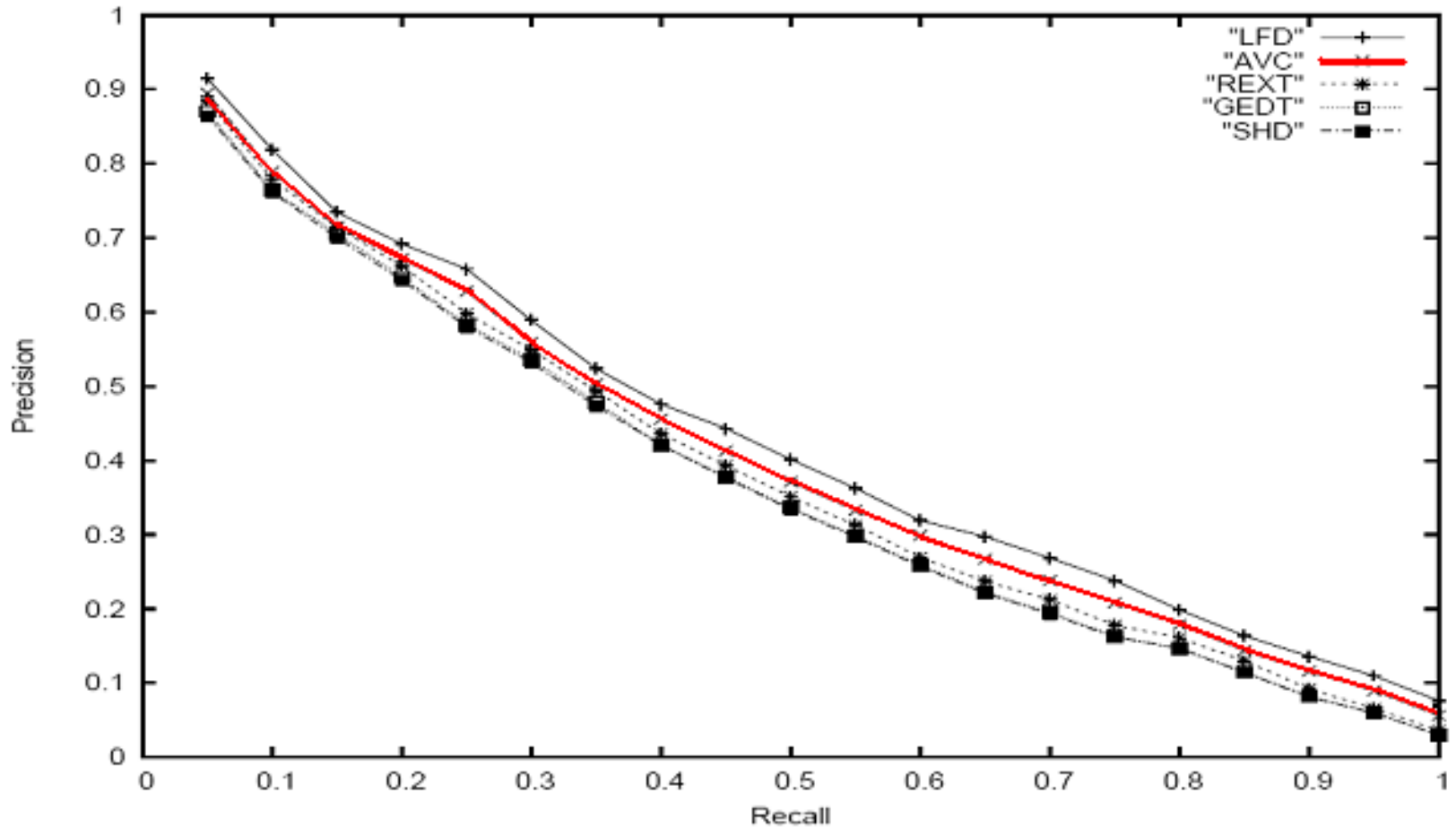
## Criteria:

- **First Tier** : the percentage of the relevant 3D-models in the first  $|C|-1$  top matches
- **Second Tier** : the percentage of the relevant 3D-models in the first  $2*|C|-1$  top matches
- **Recall** : number of relevant models retrieved /  $|C|$  (size of the relevant class)
- **Precision** : number of relevant models retrieved / number of retrieved models
- **Others** : E-Measure, Discounted Cumulative Gain (DCG), Normalised DCG (NDCG)

# PSB – Statistical Evaluation

Methods	Discrimination						
	Storage size	NN	FT	ST	E-Measure	DCG	N-DCG
LFD	4,700	65.7%	38.0%	48.7%	28.0%	64.3%	21.3%
<b>AVC(probability)</b>	<b>1113</b>	<b>62.0%</b>	<b>35.5%</b>	<b>45.51%</b>	<b>25.7%</b>	<b>63%</b>	<b>15.78%</b>
REXT	17,416	60.2%	32.7%	43.2%	25.4%	60.1%	13.3%
GEDT	32,776	60.3%	31.3%	40.7%	23.7%	58.4%	10.2%
<b>AVC(simple distance)</b>	<b>1113</b>	<b>59.8%</b>	<b>31.5%</b>	<b>41.7%</b>	<b>24.1%</b>	<b>58.9%</b>	<b>11,2%</b>
SHD	2,184	55.6%	30.9%	41.1%	24.1%	58.4%	10.2%
2-GR	512	55.5%	28.7%	39.1%	23.0%	56.3%	—%
EXT	552	54.9%	28.6%	37.9%	21.9%	56.2%	6.0%
SECSHEL	32,776	54.6%	26.7%	35.0%	20.9%	54.5%	2.8%
VOXEL	32,776	54.0%	26.7%	35.3%	20.7%	54.3%	2.4%
SECTORS	552	50.4%	24.9%	33.4%	19.8%	52.9%	-0.3%
CEGI	2,056	42.0%	21.1%	28.7%	17.0%	47.9%	-9.6%
EGI	1,032	37.7%	19.7%	27.7%	16.5%	47.2%	-10.9%
D2	136	31.1%	15.8%	23.5%	13.9%	43.4%	-18.2%
SHELLS	136	22.7%	11.1%	17.3%	10.2%	38.6%	-27.3%

# PSB – Recall/Precision



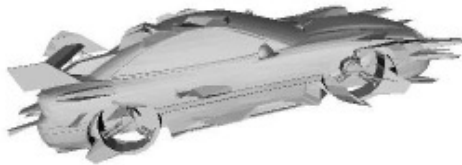
# Robustness Evaluation



(a) Original 3D-model.



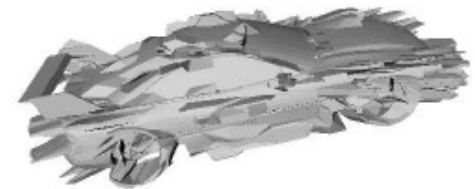
(b) Model with decimation.



(c) Model with 5% noise.

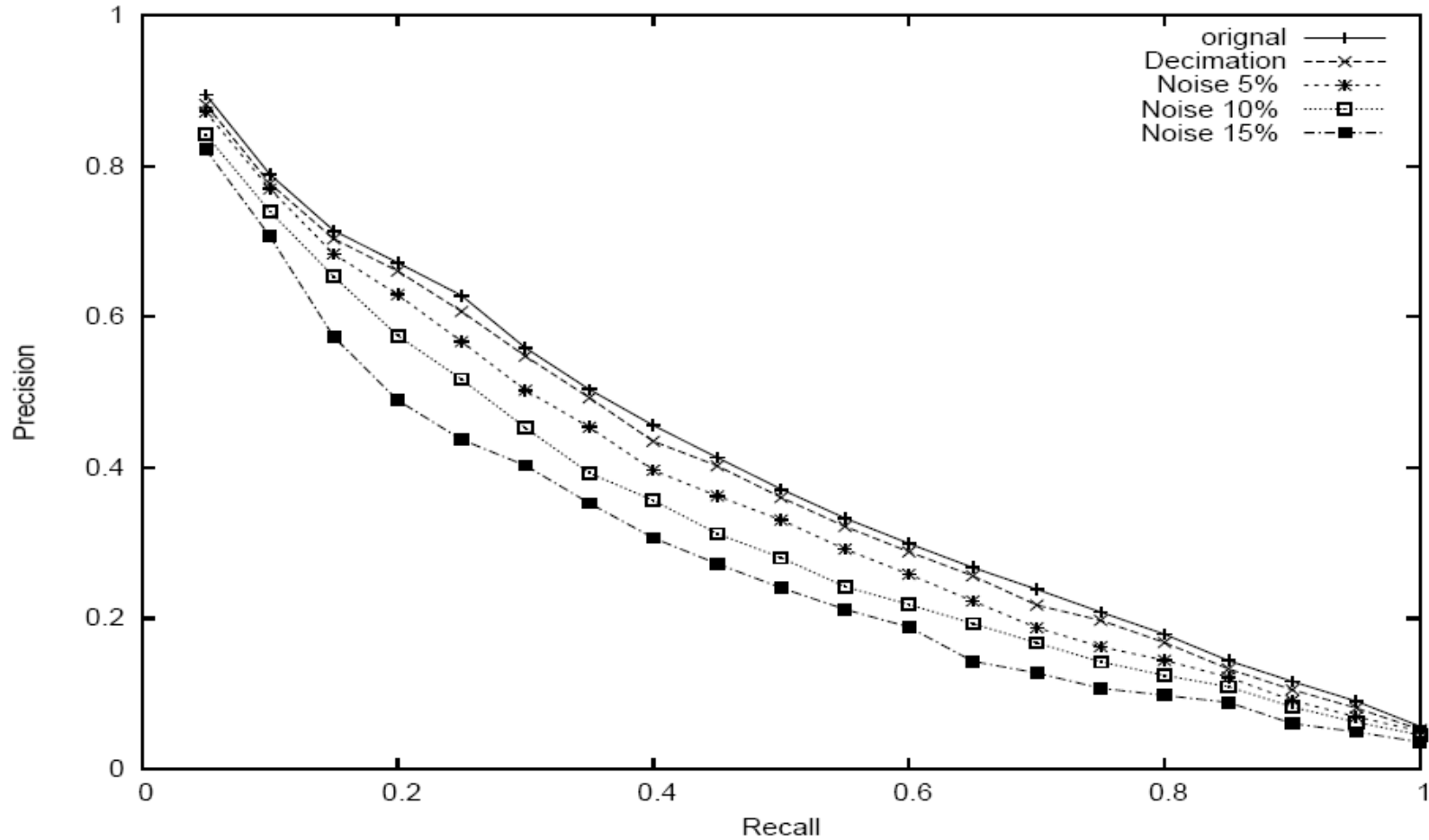


(d) Model with 10% noise.



(e) Model with 15% noise.

# Robustness Evaluation





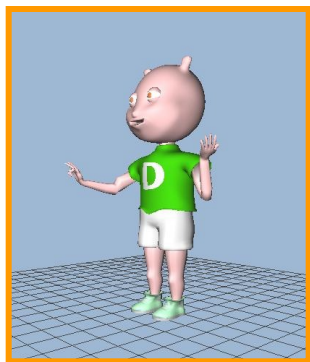
# Approche structurelle

# Structural Shape Descriptors

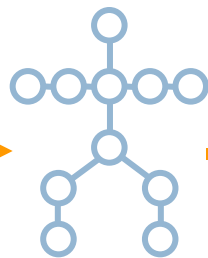
79

Approche générale:

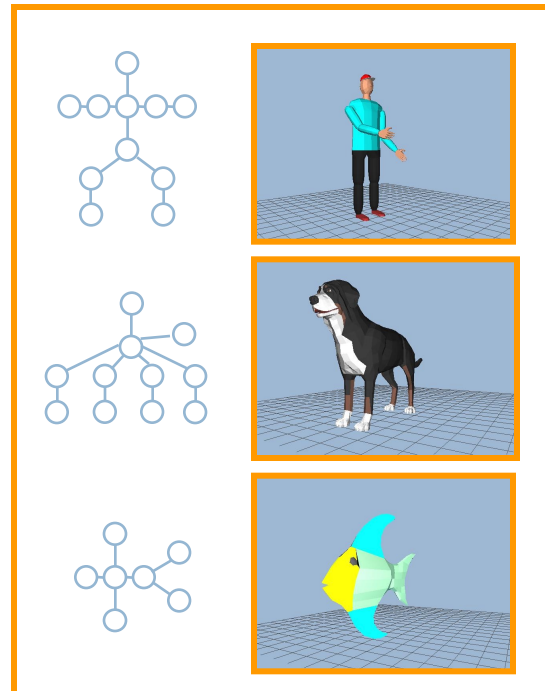
- ❑ Construire un graphe où les noeuds représentent des parties de l'objet et les arrêtes représentent les relations entre les différentes parties.
- ❑ Comparer les noeuds.
- ❑ Comparer les graphes



Requête



Descripteur  
de  
forme



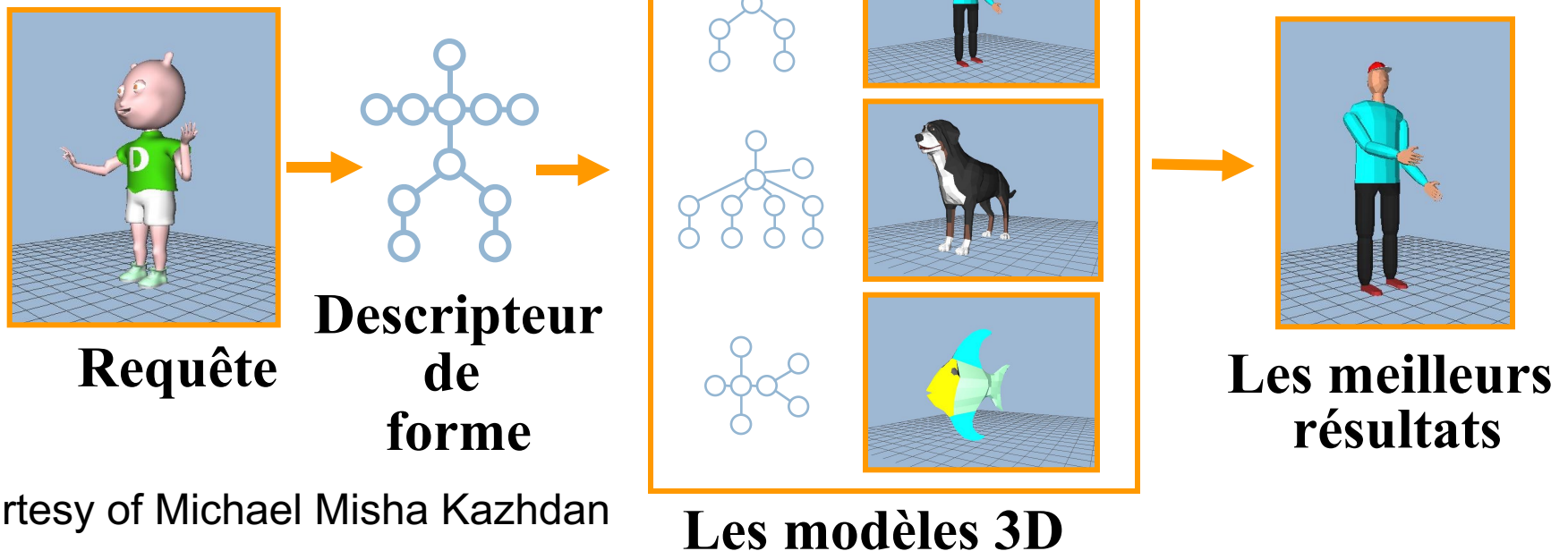
Les meilleurs  
résultats

# Structural Shape Descriptors

80

## Avantages:

- ❑ Articulation des noeuds ne changent pas le descripteur.
- ❑ Les descripteurs statistiques peuvent être utilisés pour comparer les noeuds.
- ❑ Isomorphismes de sous-graphe peut être utilisé pour faire des comparaisons partielles.





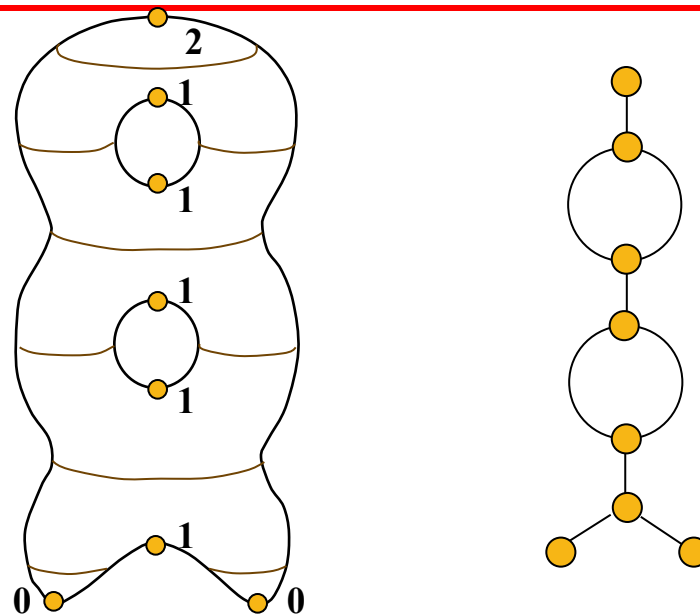
# Théorie de Morse

- Notre approche :
  - Caractériser la topologie de ces surfaces. C'est pourquoi la théorie de Morse est bien adaptée car elle permet d'étudier la relation entre des fonctions définies dans un espace et la forme de cet espace.
  - Représentation graphique par les graphes de Reeb.

# Graphe de Reeb

82

- Représentation graphique de la fonction de Morse.
- Les **arrêtes** du graphes sont les points critiques de la fonction  $f$ .
- Les **arcs** du graphes connectent les ensembles de niveau de la fonction  $f$ .

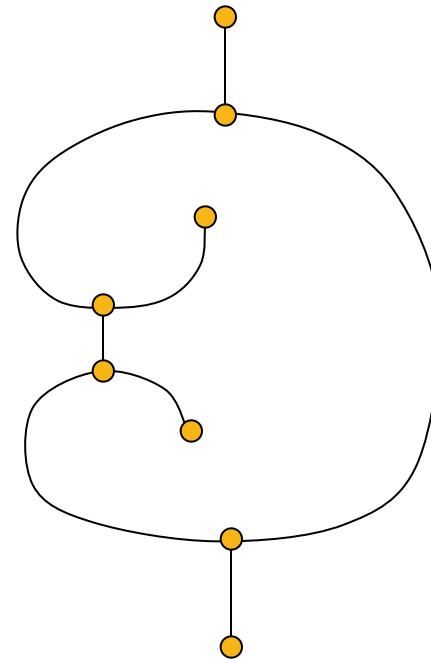
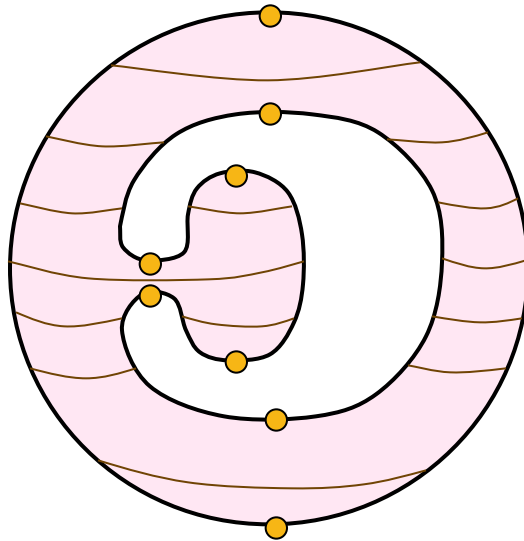


# Graphes de Reeb

83

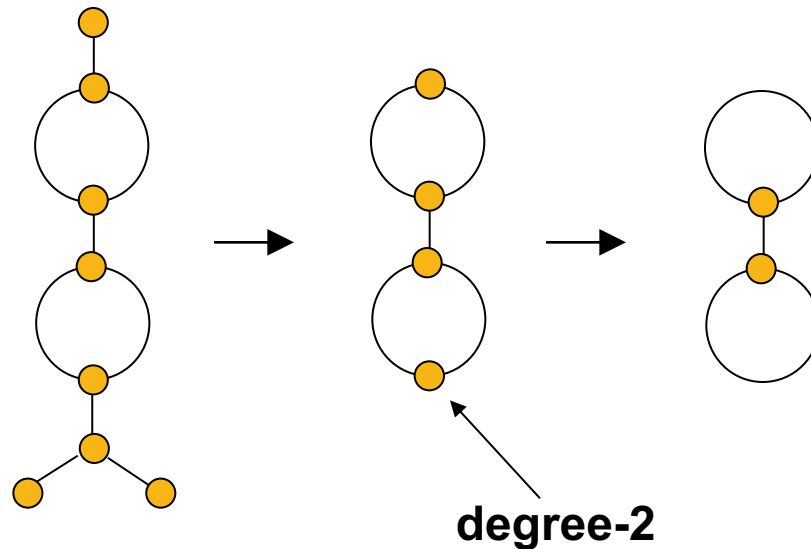
Soit la fonction continue  $\mu : S \rightarrow \mathbb{R}$  définie sur la surface  $S$  d'un objet 3D. Le graphe de Reeb est par définition l'espace quotient du graphe de  $\mu$  dans  $S$ , définie par la relation d'équivalence suivante entre  $X \in S$  et  $Y \in S$  :

$$X \sim Y \iff \begin{cases} \mu(X) = \mu(Y) \\ X \text{ et } Y \text{ sont dans une même composante connexe de } \mu^{-1}(\mu(X)) \end{cases}$$

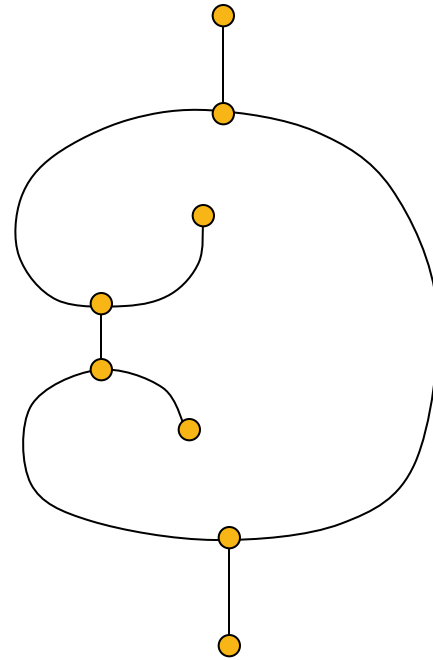
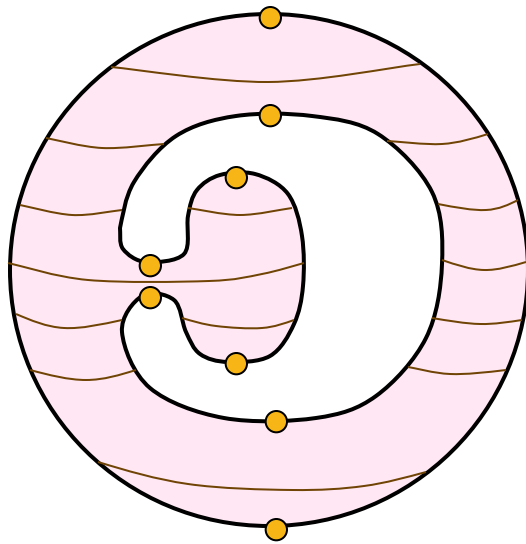


# Graphe de Reeb et genre

- 84 □ Le nombre de boucle dans le graphe de Reeb correspond au nombre de trous (genus) dans la



# Exemple de Reeb graph



# Exemple de fonction de Morse : Distance géodésique

- L'idée de [Hilaga et al. 01]: est d'utiliser la fonction géodésique comme fonction de Morse.

$$g(\mathbf{p}) = \int_M \text{geodist}(\mathbf{p}, \mathbf{q}) dS$$

$$f(\mathbf{p}) = \frac{g(\mathbf{p}) - \min_{\mathbf{q} \in M} g(\mathbf{q})}{\max_{\mathbf{q} \in M} g(\mathbf{q})}$$

# Exemple de fonctions de Morse

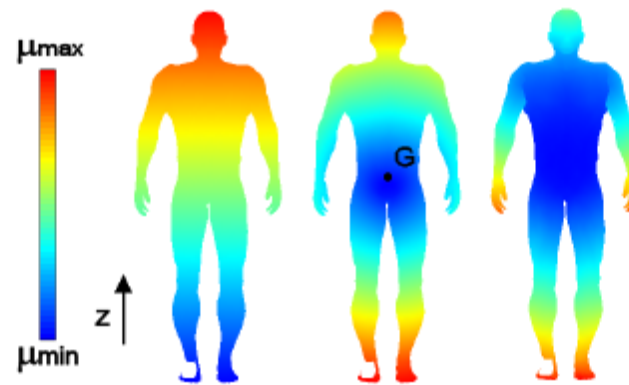
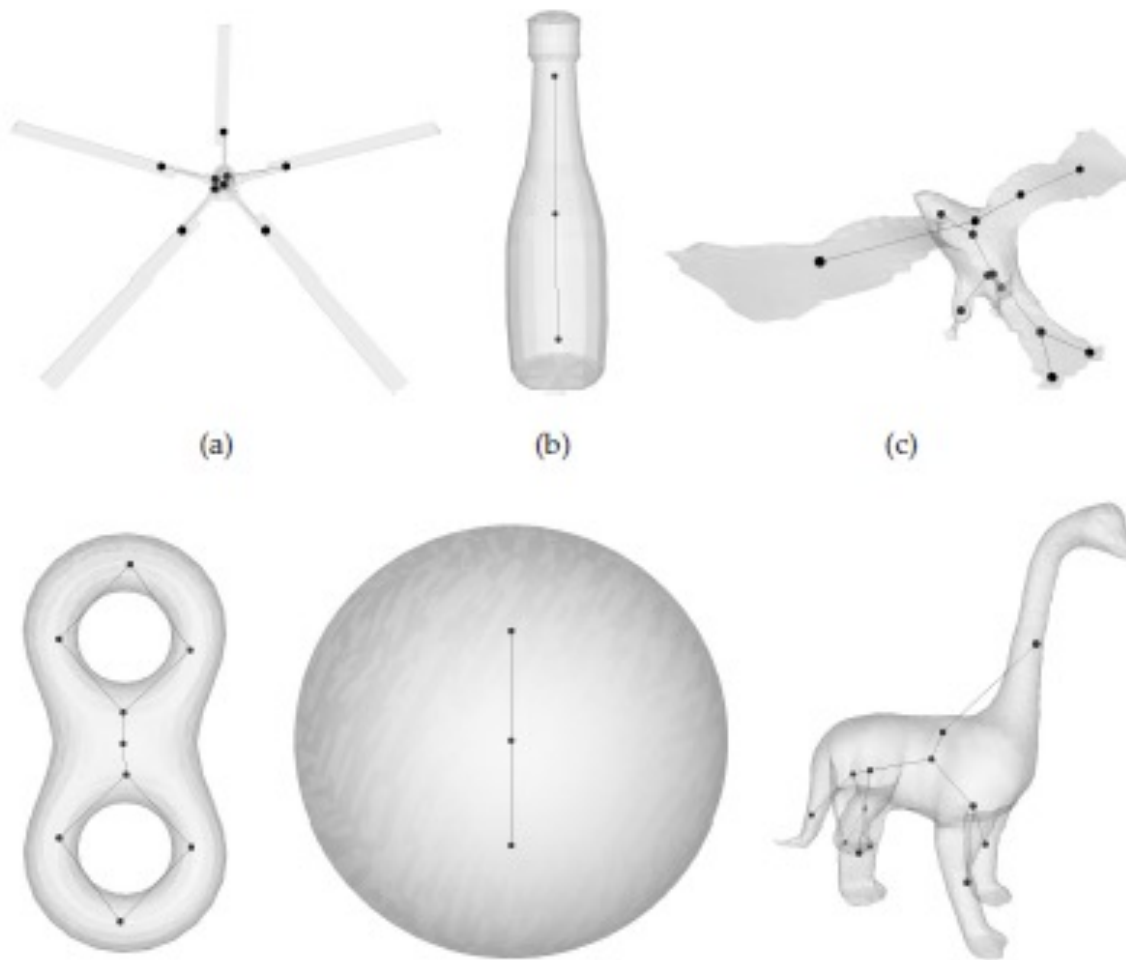


FIG. 2.3 – Exemple de fonctions  $\mu$  : hauteur (gauche), distance au centre de masse (milieu), intégrale de distance géodésique (droite).

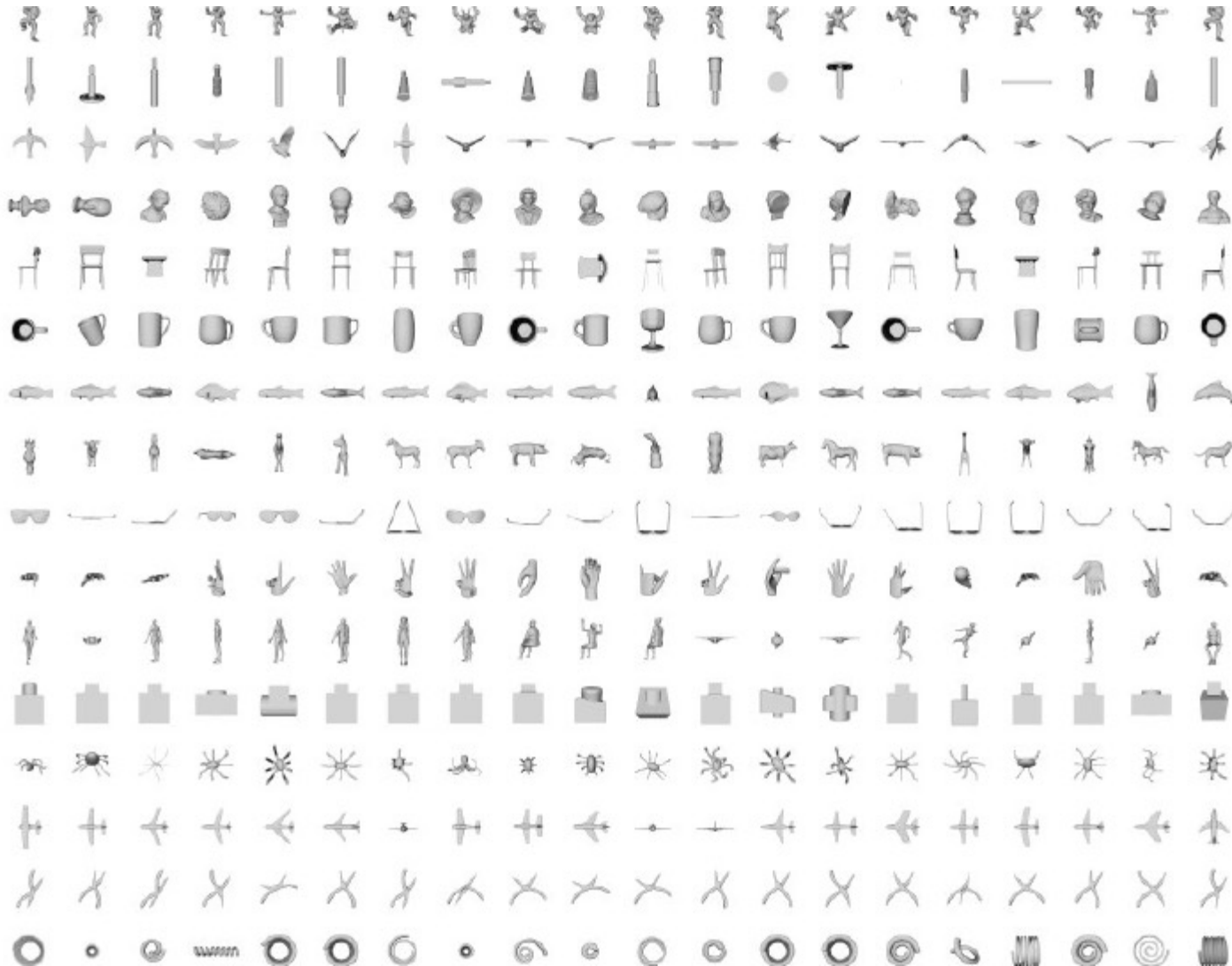
# Graphe de Reeb

88





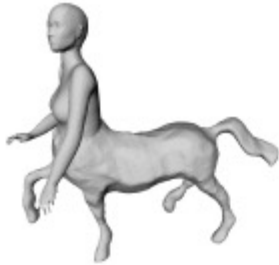
# Base Shrec 2007 (base)



# Base Shrec 2007 (les requêtes)



# Des résultats



(a)

Query



(b)

1.  $S = 0.284$



(c)

2.  $S = 0.276$



(d)

3.  $S = 0.247$



(e)



(f)



(g)



(h)

# Références Bibliographiques

- J-L. Dugelay, A. Baskurt, M. Daoudi, 3D Object Processing: Compression, Indexing and Watermarking, Wiley, 2008.
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