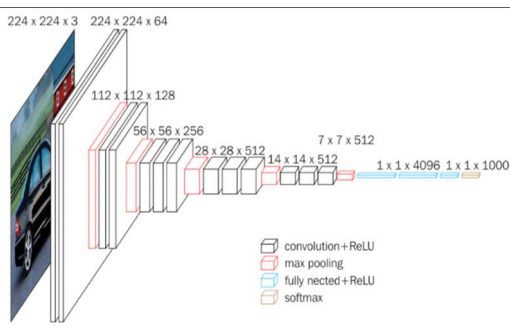
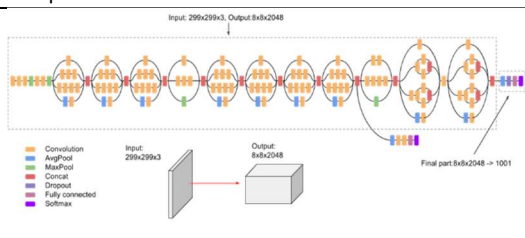


Learning and Reasoning for Cultural Metadata Quality

Supplementary electronic materials

SUPPLEMENTARY MATERIAL 1:

Table S1: Comparison of CNN models.


VGG-16 with batch normalization	Inception v3
	
1st Runner-Up in ILSVRC2014	1st Runner-up ILSVRC2015
10 classes mAP = 0.78	10 classes mAP = 0.79
~138 million parameters	~24 million parameters
~525 MB disk space	~96 MB disk space
3h35m training time	3hr15m training time




Training time was benchmarked on 40 class multi-label classifier, 55 900 training samples on cluster node with 2x Xeon SP Gold 5115 @ 2.4 GHz CPU, 256 GB RAM with 2 GeForce GTX 1080 Ti GPUs cards connected with a PCIe gen3 16x interface, 11GB of RAM per card

SUPPLEMENTARY MATERIAL 2


In Table S2 we present the examples of the artwork image classification results. These images have a common depiction of a dog and some other concepts. The prediction scores column represents the top 10 classified concepts ordered by relevance. On the first row is an example where the labels *arbre* (tree), *chien* (dog), *oiseau* (bird) correspond to the metadata and the classifier correctly identified these objects with the very high probability scores. On the second and third rows the label for a concept *chien* (dog) is semantically derived from the metadata descriptions of the dog's breeds *basset* (basset hound) and *lévrier* (greyhound) by performing reasoning on the metadata and the thesaurus. For these rows the model also correctly classifies dogs with high prediction scores. It is worth reiterating that these two images would not appear in the results of the text-based search for *chien* (dog) because this term is not explicitly mentioned in their metadata. The last row demonstrates the challenges of the image classification of the artworks. In this case only an *oiseau* (bird) is classified correctly most likely due to the style of the painting.

Table S2: Examples of prediction scores generated by DL classifier for the images representing concept *chien* (dog) among others.

Image	Labels & Metadata	Prediction
	<i>arbre</i> (tree) <i>chien</i> (dog) <i>oiseau</i> (bird) <i>scène</i> (<i>chien, chasse, canard, oiseau, arbre</i>) (scene (dog, hunt, duck, bird, tree)) 000PE009118	<i>oiseau</i> (bird) : 0.998 <i>arbre</i> (tree) : 0.967 <i>chien</i> (dog) : 0.961 <i>mouton</i> (sheep) : 0.798 <i>montagne</i> (mountain) : 0.646 <i>fleur</i> (flower) : 0.638 <i>lion</i> : 0.359 <i>maison</i> (house) : 0.357 <i>pont</i> (bridge) : 0.285 <i>nu</i> (nude) : 0.199

	<i>chien</i> (dog) représentation animalière (basset, forêt) (animal representation (basset hound, forest)) 000PE000878	<i>chien</i> (dog): 0.998 <i>oiseau</i> (bird): 0.746 lion : 0.714 <i>arbre</i> (tree): 0.435 <i>cheval</i> (horse): 0.421 <i>mouton</i> (sheep): 0.400 <i>maison</i> (house): 0.183 table : 0.143 <i>cavalier</i> (horseman): 0.125 <i>de profil</i> (sideways) : 0.110
	<i>chien</i> (dog) <i>scène</i> (chasse : lévrier, lièvre) (scene (hunting: greyhound, rabbit)) M0810001165	<i>chien</i> (dog): 0.993 <i>cheval</i> (horse): 0.765 lion : 0.609 <i>oiseau</i> (bird): 0.473 <i>mouton</i> (sheep): 0.422 <i>de profil</i> (sideways) : 0.235 <i>arbre</i> (tree): 0.124 <i>cavalier</i> (horseman): 0.112 <i>fleur</i> (flower): 0.079 <i>feuille</i> (leaf) : 0.036
	<i>chien</i> (dog) <i>oiseau</i> (bird) <i>nature morte</i> (lièvre, passereau, fusil, récipient : cuivre) ; <i>chien</i> (still life (rabbit, sparrow, gun, container: copper); dog) 000PE018922	<i>oiseau</i> (bird): 0.900 <i>chien</i> (dog): 0.030 <i>fleur</i> (flower): 0.014 table : 0.013 <i>arbre</i> (tree): 0.007 <i>feuille</i> (leaf) : 0.006 lion : 0.003 <i>mouton</i> (sheep): 0.002 <i>bateau</i> (boat) : 0.002 <i>mer</i> (sea): 0.002

As another example of the benefit of both the semantic reasoning on label creation and prediction score utilization, the sculpture from the 3rd row of Table S2 is simply not found as a result of the current search on the French Ministry of Culture portal for *chien* (dog) by Pierre-Jules Mêne (Figure 1). Because the word *chien* (dog) is not explicitly mentioned in the metadata. And the dog is annotated by its breed *lévrier* (greyhound)



POP : la plateforme ouverte du patrimoine

Panier vide

Votre avis est utile


Votre recherche

Recherche avancée

chien


LISTE CARTE MOSAIQUE

4 résultats




Valet de chien à cheval menant sa harde
groupe relié
MENE Pierre Jules : France
1869
Paris : musée du Louvre

Jocinde
M5037011442
Ajouter au panier




Sanglier coiffé par les chiens
statuette
MENE Pierre Jules
2e quart 19e siècle, 2e moitié 19e siècle
Senlis : musée de la Vénérrie

Jocinde
M0810001164
Ajouter au panier



CHIENS AU TERRIER
groupe relié
MENE Pierre Jules : France
1853
Paris : musée d'Orsay

Jocinde
0005C011504
Ajouter au panier




Hallali du sanglier
MENE Pierre Jules : France
1846
Chantilly : musée Condé

Jocinde
00000105149
Ajouter au panier

Figure S1: Top 4 search results on the concept *chien* (dog) and sculpture by Plerre Jules Mêne extracted from the Open Heritage Platforme (POP: la plateforme ouverte du patrimoine) maintained by the French Ministry of Culture.

By contrast, the thesaurus based labeling mechanism and 40-class classifier we proposed are able to identify a dog on this image with the highest degree of certainty as seen in Table S3.

Table S3: Labels, metadata and prediction scores of the artwork ID M0810001165.

Image	Labels & Metadata	Prediction Scores
	chien (dog) scène (chasse : lévrier, lièvre) (scene (hunting: greyhound, rabbit)) M0810001165	chien (dog): 0.993 cheval (horse): 0.765 lion : 0.609 oiseau (bird): 0.473 mouton (sheep): 0.422 de profil (sideways) : 0.235 arbre (tree): 0.124 cavalier (horseman): 0.112 fleur (flower): 0.079 feuille (leaf) : 0.036

Running the same query on the Extended Joconde dataset and sorting by score gives the results shown in Table S4 where we can see above-mentioned artwork appears in second place.

Table S4: Top 4 search result on the term *chien* (dog) and sculpture by Pierre Jules Mene would look like if done on the Extended Joconde dataset

Image	Joconde Metadata	Prediction Score
	représentation animalière (épagneul, debout) (animal representation (spaniel, standing)) M0341003743	chien (dog): 0.994
	scène (chasse : lévrier, lièvre) (scene (hunting: greyhound, rabbit)) M0810001165	chien (dog): 0.993
	représentation animalière (mise à mort, gros gibier : sanglier, chasse à courre, chien) (animal representation (killing, big game: wild boar, hunt, dog)) 00000105149	chien (dog): 0.990
	scène (chasse : sanglier, chien) (scene (hunting: boar, dog)) M0810001164	chien (dog): 0.987

SUPPLEMENTARY MATERIAL 3

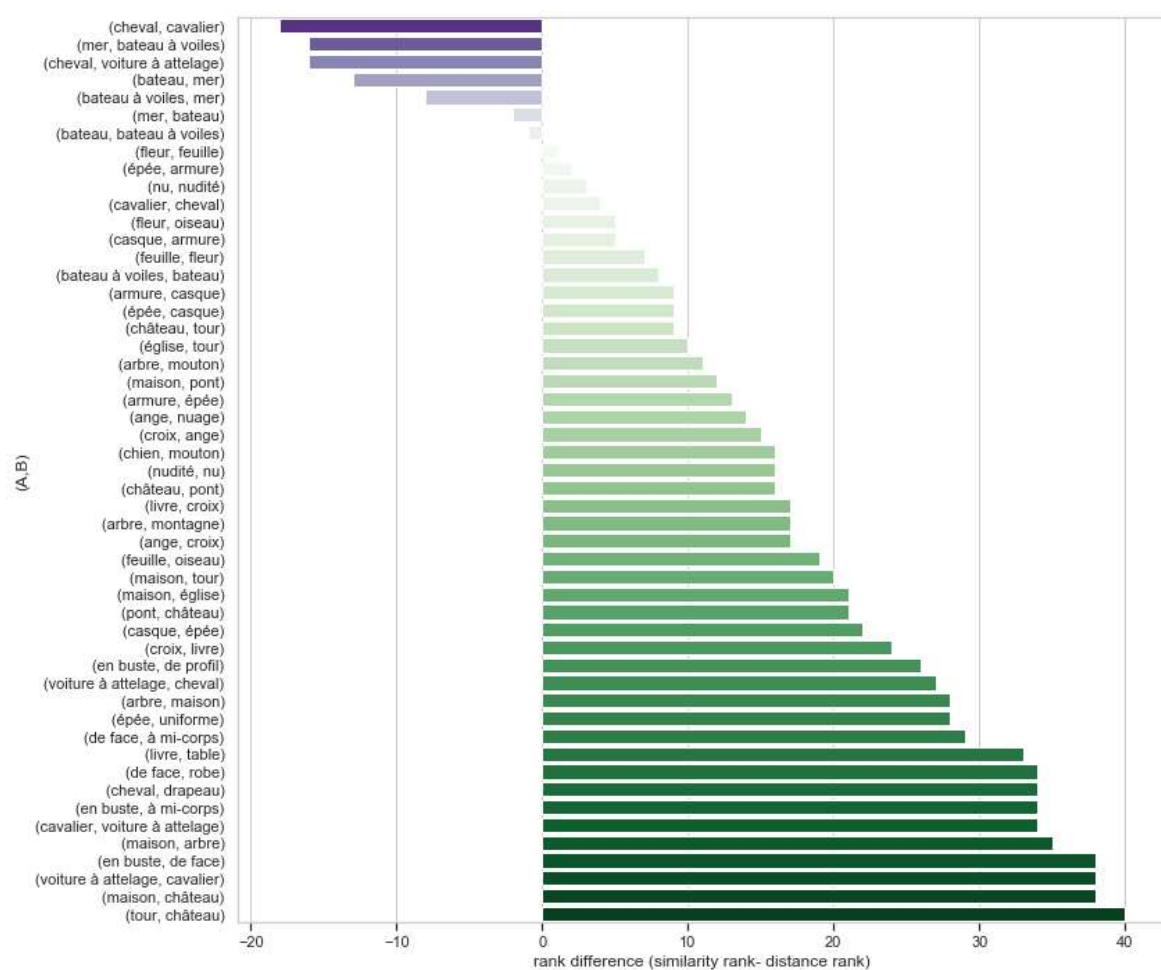


Figure S2 Full chart of low (negative and close to negative) rank difference indicates that the concepts pairs that are not closely related by Garnier Thesaurus but are similar by the predictions (score > 0.9) context.

SUPPLEMENTARY MATERIAL 4

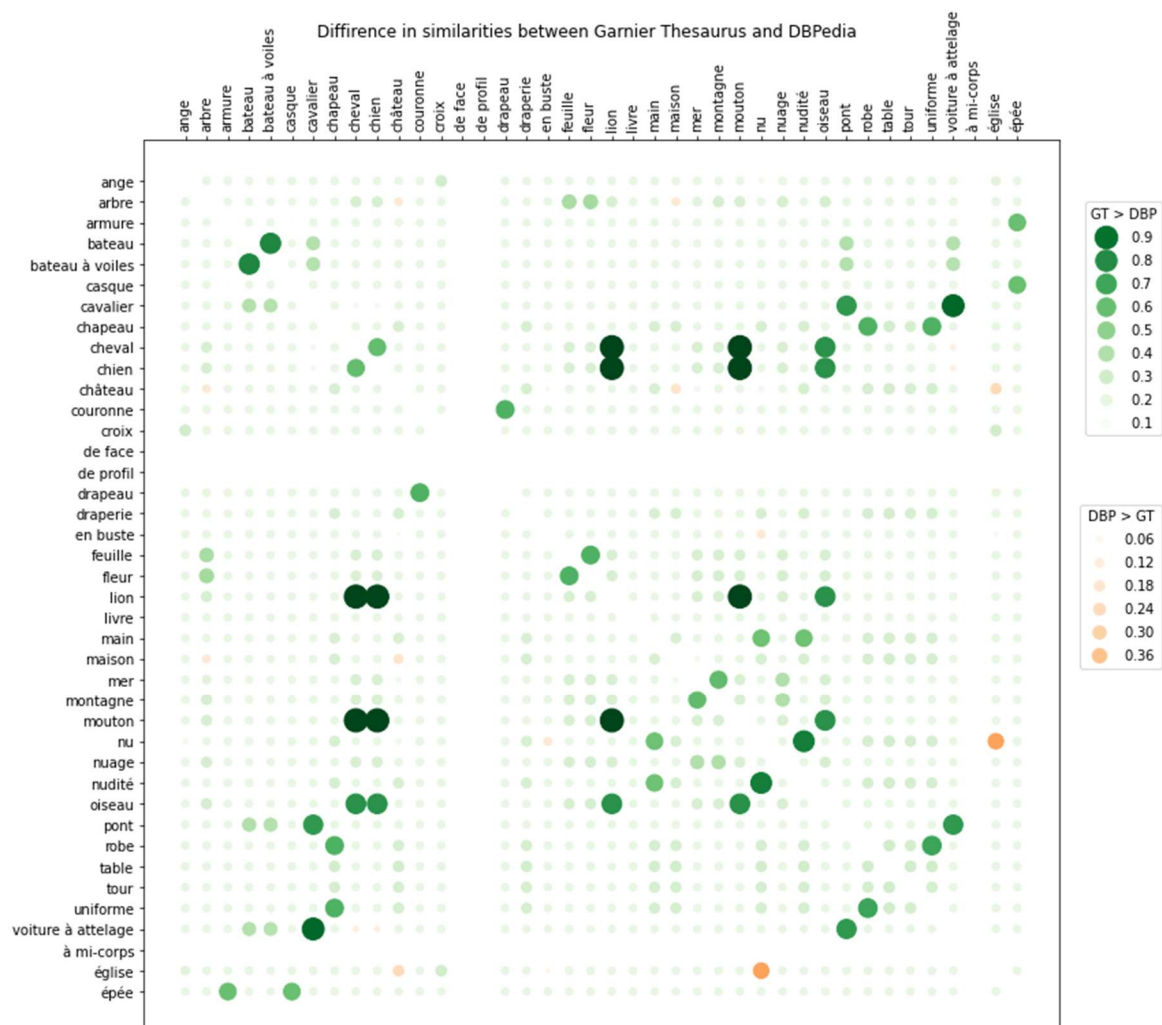


Figure S3: Full scale bubble chart of the similarity differences between the sub-graphs extracted from Garnier Thesaurus and DBPedia.fr with ancestry depth 6. Large circles represent large differences between the similarities. Green circles mean that concept pairs are more similar in Garnier Thesaurus and orange circles mean that concept pairs are more similar in DBPedia.fr.

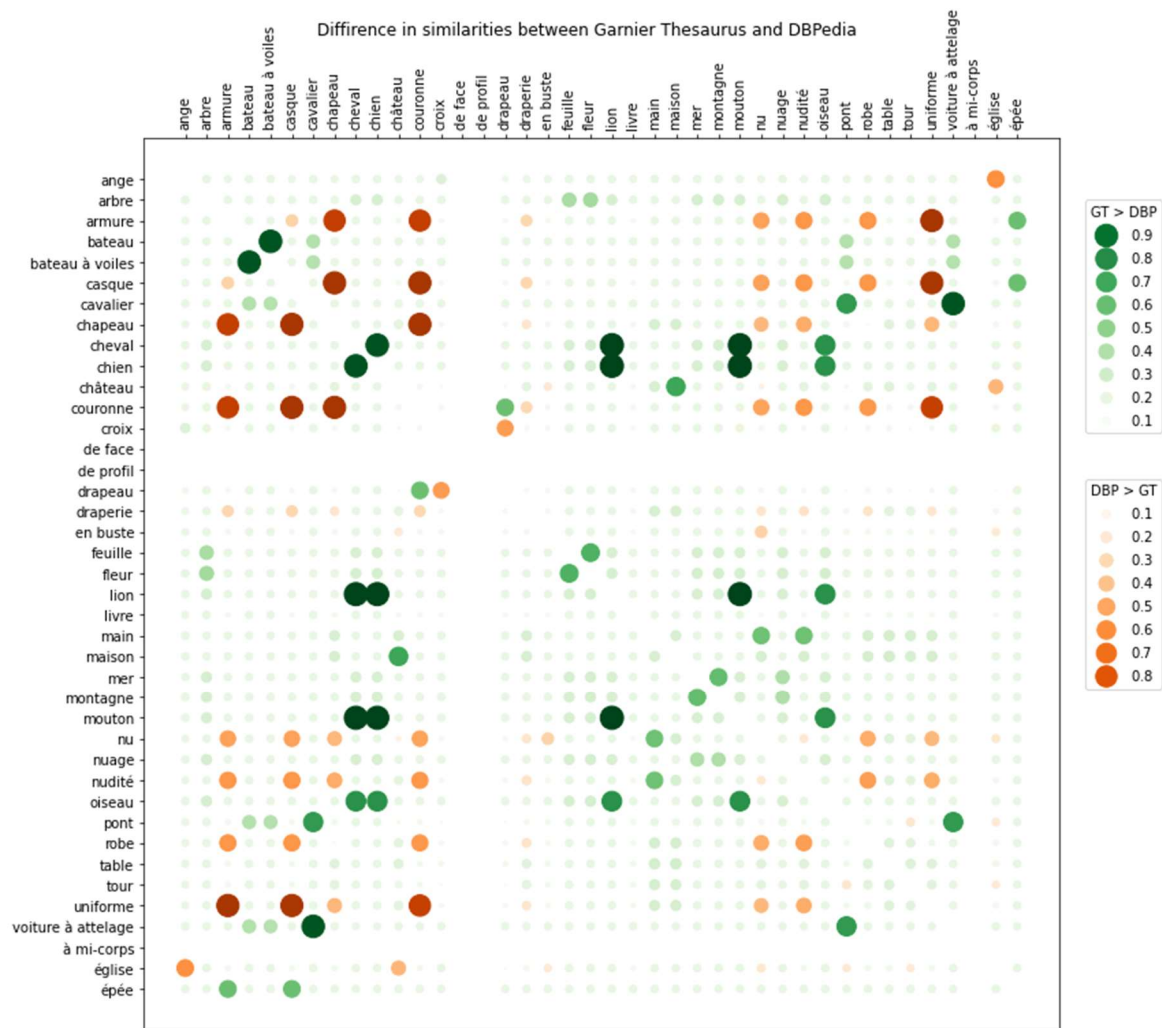


Figure S4: Full scale bubble chart of the similarity differences between the sub-graphs extracted from Garnier Thesaurus and DBPedia.fr with ancestry depth 3. Large circles represent large differences between the similarities. Green circles mean that concept pairs are more similar in Garnier Thesaurus and orange circles mean that concept pairs are more similar in DBPedia.fr.

SUPPLEMENTARY MATERIAL 5

Table S5: List of mostly searched concepts provided by the French Ministry of Culture. The list is sorted by the number of available images representing a concept in descending order and should be read from top to bottom and from left to right. In bold are the concepts with sufficient number of images for training a Deep Learning Model.

arbre	croix	bâton	Christ en croix	éléphant
en buste	cavalier	port	chaussure	pipe
fleur	épée	parc	trône	lettre
nu	voiture à attelage	manteau	bonnet	phare
cheval	pont	vache	papillon	roue
maison	main	escalier	chat	horloge
oiseau	mer	fusil	arc	couteau
bateau	nudité	lit	lyre	guitare
église	feuille	pêche	tonneau	train
de profil	bateau à voiles	cerf	tente	harpe
à mi-corps	armure	cimetière	singe	automobile
chien	uniforme	bouclier	sac	arc monumental
de face	casque	sanglier	bouteille	assiette
ange	table	porte	plage	ours
couronne	tour	fenêtre	neige	seau
livre	lion	arcade	flûte	bicyclette
chapeau	drapeau	chaise	éventail	pyramide
draperie	mouton	pot	échelle	grenouille
château	nuage	flèche	moulin à vent	avion
montagne	robe	poisson	rideau	piano
			arènes	aérostat