Supplementary for Hierarchical Granularity Transfer Learning

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1 Granularity Gap between Two Domains

Since $\boldsymbol{a}(y_b)$ and $\boldsymbol{a}(y_s)$ share a common semantic space, $g(\cdot)$ can be transferred to $\boldsymbol{a}(y_s)$ to interpret the sub-category descriptions. Thus, an intuitive solution for HGTL is to directly transfer both $f_v(\cdot)$ and $g(\cdot)$ to sub-domain by:

$$\hat{y}_s = \arg\min_{y \in \mathcal{Y}_s} d[f_v(\boldsymbol{x}), g(\boldsymbol{a}(y))]. \tag{1}$$

However, Eq. (1) suffers from the serious granularity gap of visual representations. Specifically, $\mathcal{L}_{sa}$ constrains $f_v(\boldsymbol{x})$ to give a small inner-class divergence of basic-categories, but this inner-class divergence is desired to be preserved to distinguish subordinate categories y_s as shown in Figure 1. Assume that two images $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$ have the same basic-category y_b and different sub-categories y_s, minimizing $\mathcal{L}_{sa}$ encourages $f_v(\boldsymbol{x}_1)$ and $f_v(\boldsymbol{x}_2)$ to be aligned with the same $\boldsymbol{a}(y_b)$, thereby making $f_v(\boldsymbol{x}_1)$ and $f_v(\boldsymbol{x}_2)$ hard to separate in the sub-category domain for different $\boldsymbol{a}(y_s)$.

In summary, HGTL suffers from the granularity gap, *i.e.,* some images have the same training basic-category but different testing sub-categories. As shown in Fig. 1 (a), in the basic-domain, we target to minimize the inner-class divergences of “Albatross" and “Auklet" samples to distinguish these two basic-categories accurately. However, when the model is transferred to the sub-domain for testing, all the samples belonging to “Albatross" are clustered compactly, which impedes the further subdivision for “Footed Albatross" and “Laysan Albatross".

2 Visualized Attention Maps

As illustrated in the main text, the $f_{pv}(\cdot)$ can localize informative local part regions to generate discriminative features. Here, we visualize some generated attention maps for $f_{pv}(\cdot)$ in Figure 2. From the results, by leveraging the attention mechanism, $f_{pv}(\cdot)$ can effectively localize the important regions. Specifically, different attention parts can localize complementary regions, *e.g.,* head and wing, which proved subtle visual clues to distinguish intra-class difference.

3 Some Recognition Results

Some qualitative results of BigSPN for both basic and subordinate categories are given in Fig. 3. It can be seen that the basic-level categories can be easily recognized correctly due to the obvious shape and texture difference. However, when coming to the sub-level categories, some samples are incorrectly recognized.

4 Details for datasets

Here, we give detailed hierarchical granularity trees for all three datasets in Table 1, Table 2, and Figure 4. The hierarchical granularity trees are built according to biology Taxonomy [1, 2]. Each basic-level class contains several sub-level categories that have many common characteristics, and

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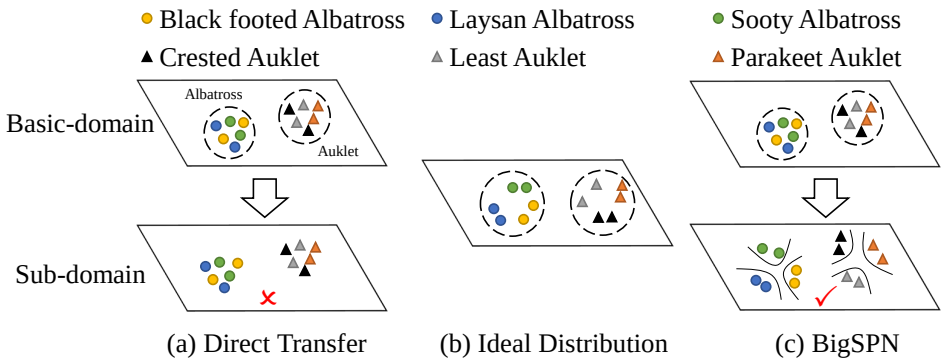

Figure 1: A comparison between general knowledge transfer and the proposed BigSPN.

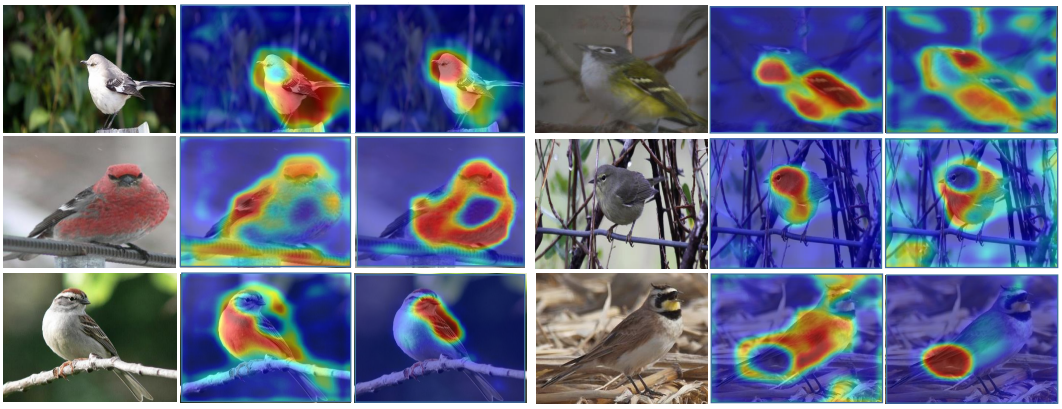

Figure 2: Some results obtained from $f_{pv}(\cdot)$. We randomly select two attention maps generated by $R_k(\cdot)$ for each image.

different sub-level categories have subtle visual differences. During training stage, CUB-HGTL, AWA2-HGTL, and Flower-HGTL only provide image annotations of basic-categories, and semantic descriptions for both basic and sub(ordinate)-level categories. During testing stage, the task is how to predict the sub-level category for an input image.

The detailed dataset information is given in the “CUB", “AWA2", and “FLO" folders, respectively, as well as the train/val splits and all category descriptions.

References

[1] Simpson, G.G.: Principles of animal taxonomy (1961)

[2] Wheeler, Q.D.: Taxonomic triage and the poverty of phylogeny. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences **359**(1444), 571–583 (2004)

Table 1: Detailed hierarchical granularity tree for Flower-HGTL.

	Basic	Subordinate
Flowers	Ambelliferae	great masterwort.
	Aquifoliaceae	alpine sea holly.
	Aroideae	anthurium, giant white arum lily.
	Asteraceae	artichoke, barbeton daisy, bishop of llandaff, blanket flower, marigold, mexican aster, moon orchid, orange dahlia, osteospermum, oxeye daisy, colt's foot, common dandelion, english marigold, pink-yellow dahlia, purple coneflower, spear thistle, gazania, globe thistle, sunflower.
	Ericaceae	azalea.
	Campanulaceae	balloon flower, canterbury bells.
	Iridaceae	bearded iris, blackberry lily, spring crocus, sword lily, yellow iris.
	Lamiaceae	bee balm.
	Strelitziaceae	bird of paradise.
	Acahaceae	black-eyed susan, mexican petunia.
	Nyctaginaceae	bougainvillea.
	Bromeliaceae	ball moss, bromelia.
	Proteaceae	king protea.
	Ranunculaceae	lenten rose, buttercup, clematis, japanese anemone.
	Nymphaeaceae	lotus, water lily.
	Ranunculaceae	love in the mist, columbine, windflower.
	Magnoliaceae	magnolia.
	Malvaceae	mallow, hibiscus, tree mallow.
	Monkshood	monkshood.
	Convolvulaceae	morning glory, silverbush.
	Passifloraceae	passion flower.
	Geraniaceae	pelargonium, geranium.
	papaveraceae	californian poppy, corn poppy, tree poppy.
	theaceae	camellia.
	Cannaceae	canna lily.
	caryophyllaceae	carnation, sweet william.
	Zingiberaceae	cautleya spicata, red ginger.
	Primulaceae	cyclamen, pink primrose, primula.
	Amaryllidaceae	cape flower, daffodil, peruvian lily, hippeastrum.
	Apocynaceae	desert-rose, frangipani.
	Solanaceae	petunia, thorn apple.
	Euphorbiaceae	poinsettia.
	Rosaceae	rose.
	Orchidaceae	ruby-lipped cattleya, hard-leaved pocket orchid.
	liliaceae	siam tulip, fire lily, fritillary, grape hyacinth, tiger lily, toad lily.
	Scrophulariaceae	snapdragon, foxglove.
	Polemoniaceae	garden phlox.
	onagraceae	gaura.
	Tropaeolaceae	globe-flower.
	gentianaceae	bolero deep blue, stemless gentian.
	Leguminosae	sweet pea.
	Bignoniaceae	trumpet creeper.
	Cruciferae	wallflower.
	Piperaceae	watercress.
	Violaceae	wild pansy.
	Amaranthaceae	prince of wales feathers.
	caprifoliaceae	pincushion flower.

Table 2: Detailed hierarchical granularity tree for CUB-HGTL.

	Basic	Subordinate
Birds	Albatross	Black footed Albatross, Laysan Albatross, Sooty Albatross.
	Ani	Groove billed Ani.
	Auklet	Crested Auklet, Least Auklet, Parakeet Auklet, Rhinoceros Auklet.
	Blackbird	Brewer Blackbird, Red winged Blackbird, Rusty Blackbird, Yellow headed Blackbird.
	Bobolink	Bobolink.
	Bunting	Indigo Bunting, Lazuli Bunting, Painted Bunting.
	Cardinal	Cardinal.
	Catbird	Spotted Catbird, Gray Catbird.
	Chat	Yellow breasted Chat.
	Towhee	Eastern Towhee.
	Widow	Chuck will Widow.
	Cormorant	Brandt Cormorant, Red faced Cormorant, Pelagic Cormorant.
	Cowbird	Bronzed Cowbird, Shiny Cowbird.
	Creeper	Brown Creeper.
	Crow	American Crow, Fish Crow.
	Cuckoo	Black billed Cuckoo, Mangrove Cuckoo, Yellow billed Cuckoo.
	Finch	Gray crowned Rosy Finch, Purple Finch.
	Flicker	Northern Flicker.
	Flycatcher	Acadian Flycatcher, Great Crested Flycatcher, Least Flycatcher, Olive sided Flycatcher, Scissor tailed Flycatcher, Vermilion Flycatcher,Yellow bellied Flycatcher.
	Frigatebird	Frigatebird.
	Fulmar	Northern Fulmar.
	Gadwall	Gadwall.
	Goldfinch	American Goldfinch, European Goldfinch.
	Grackle	Boat tailed Grackle.
	Grebe	Eared Grebe, Horned Grebe, Pied billed Grebe, Western Grebe.
	Grosbeak	Blue Grosbeak, Evening Grosbeak, Pine Grosbeak, Rose breasted Grosbeak.
	Guillemot	Pigeon Guillemot.
	Gull	California Gull, Glaucous winged Gull, Heermann Gull, Herring Gull, Ivory Gull, Ring billed Gull, Slaty backed Gull, Western Gull.
	Hummingbird	Anna Hummingbird, Ruby throated Hummingbird, Rufous Hummingbird.
	Violetear	Green Violetear.
	Jaeger	Long tailed Jaeger, Pomarine Jaeger.
	Jay	Blue Jay, Florida Jay, Green Jay.
	Junco	Dark eyed Junco.
	Kingbird	Tropical Kingbird, Gray Kingbird.
	Kingfisher	Belted Kingfisher, Green Kingfisher, Pied Kingfisher, Ringed Kingfisher, White breasted Kingfisher.
	Kittiwake	Red legged Kittiwake.
	Lark	Horned Lark.
	Loon	Pacific Loon.
	Mallard	Mallard.
	Meadowlark	Western Meadowlark.
	Merganser	Hooded Merganser, Red breasted Merganser.
	Mockingbird	Mockingbird.
	Nighthawk	Nighthawk.
	Nutcracker	Clark Nutcracker.
	Nuthatch	White breasted Nuthatch.
	Oriole	Baltimore Oriole, Hooded Oriole, Orchard Oriole, Scott Oriole.
	Ovenbird	Ovenbird.
	Pelican	Brown Pelican, White Pelican.
	Pewee	Western Wood Pewee.
	Sayornis	Sayornis.
	Pipit	American Pipit.
	Will	Whip poor Will.
	Puffin	Horned Puffin.
	Raven	Common Raven, White necked Raven.
	Redstart	American Redstart.
	Geococcyx	Geococcyx.
	Shrike	Loggerhead Shrike, Great Grey Shrike.
	Sparrow	Baird Sparrow, Black throated Sparrow, Brewer Sparrow, Chipping Sparrow, Clay colored Sparrow, House Sparrow, Field Sparrow, Fox Sparrow, Grasshopper Sparrow, Harris Sparrow, Henslow Sparrow, Le Conte Sparrow, Lincoln Sparrow, Nelson Sharp tailed Sparrow, Savannah Sparrow, Seaside Sparrow, Song Sparrow, Tree Sparrow, Vesper Sparrow, White crowned Sparrow, White throated Sparrow.
	Starling	Cape Glossy Starling.
	Swallow	Bank Swallow, Barn Swallow, Cliff Swallow, Tree Swallow.
	Tanager	Scarlet Tanager, Summer Tanager.
	Tern	Artic Tern, Black Tern, Caspian Tern, Common Tern, Elegant Tern, Forsters Tern, Least Tern, Green tailed Towhee.
	Thrasher	Brown Thrasher, Sage Thrasher.
	Vireo	Black capped Vireo, Blue headed Vireo, Philadelphia Vireo, Red eyed Vireo, Warbling Vireo, White eyed Vireo, Yellow throated Vireo.
	Warbler	Bay breasted Warbler, Black and white Warbler, Black throated Blue Warbler, Blue winged Warbler, Chestnut sided Warbler, Golden winged Warbler, Hooded Warbler, Kentucky Warbler, Magnolia Warbler, Mourning Warbler, Myrtle Warbler, Nashville Warbler, Orange crowned Warbler, Palm Warbler, Pine Warbler, Prothonotary Warbler, Swainson Warbler, Tennessee Warbler, Wilson Warbler, Worm eating Warbler, Prairie Warbler,Canada Warbler,Cerulean Warbler,Cape May Warbler,Yellow Warbler.
	Waterthrush	Northern Waterthrush, Louisiana Waterthrush.
	Waxwing	Bohemian Waxwing, Cedar Waxwing.
	Woodpecker	American Three toed Woodpecker, Pileated Woodpecker, Red bellied Woodpecker, Red cockaded Woodpecker, Red headed Woodpecker, Downy Woodpecker.
	Wren	Bewick Wren, Cactus Wren, Carolina Wren, House Wren, Marsh Wren, Rock Wren, Winter Wren.
	Yellowthroat	Common Yellowthroat.

Figure 3: Some results on CUB-HGTL and AWA2-HGTL. Besides the images, the input of BigSPN includes auxiliary category descriptions for both basic- and sub-levels. The red color indicates incorrect prediction.

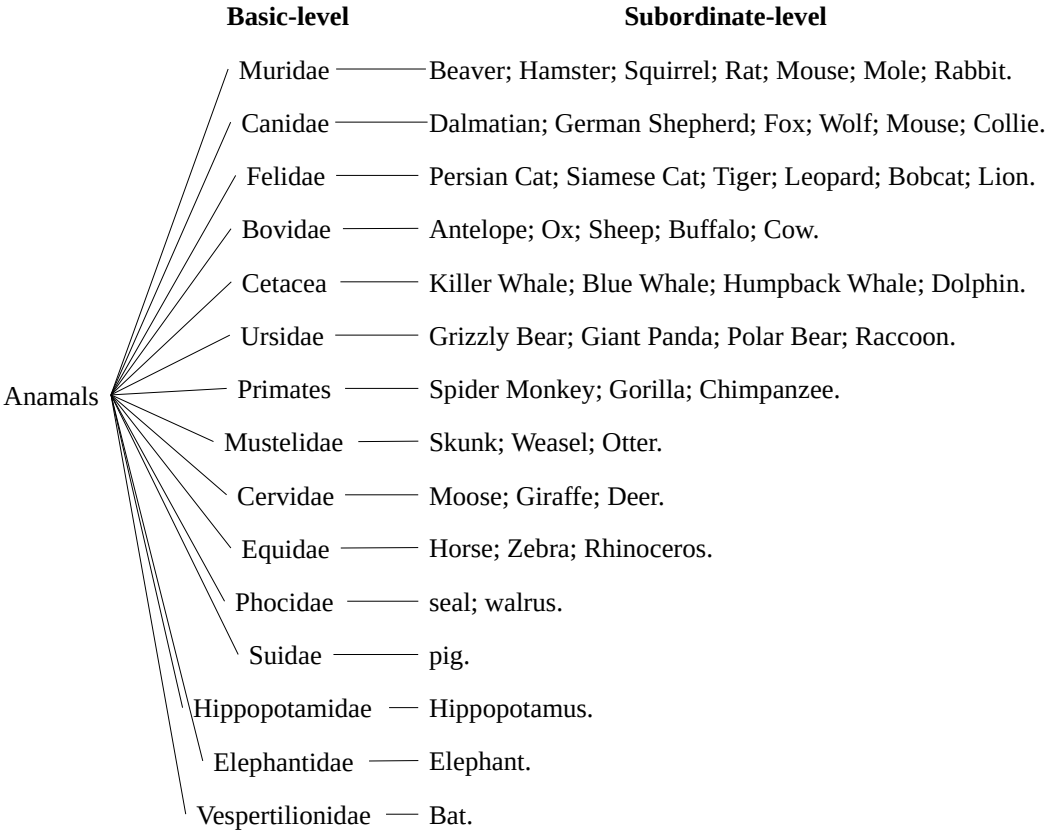

Figure 4: Detailed hierarchical granularity tree for AWA2-HGTL.