Supplementary materials for HCV: Hierarchy-Consistency Verification for Incremental Implicitly-Refined Classification

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1 Confusion matrices

Fig. 7 and Fig. 8 show the confusion matrices after learning task 11 and the last task under IIRC-2-CIFAR setup. We can observe similar trends as in Fig. 5 in the main paper when applying the HCV modules to training and inference stages of iCaRL-CNN.

2 Infer-HCV

We verify the hierarchy consistency also at inference time (see Section 3.2). Here we provide some examples for better understanding of Infer-HCV. In Fig. 9 there are four examples of how the *Infer-HCV* module works. We address the examples one column at a time:

I. This example is correctly matched by the first row of H_t, so it remains unchanged.

II. This example does not match any row in H_t. We match it with the first row by removing the second label.

III. This example also does not match. We match it by adding the first class label to make it in accordance with the last row of H_t.

IV. This example also does not match. It can be modified by removing the 4th or 5th labels, so we randomly choose one from them to make it compatible with H_t.

(a) Ground truth   (b) iCaRL-CNN   (c) + SPL   (d) +SPL+HCV

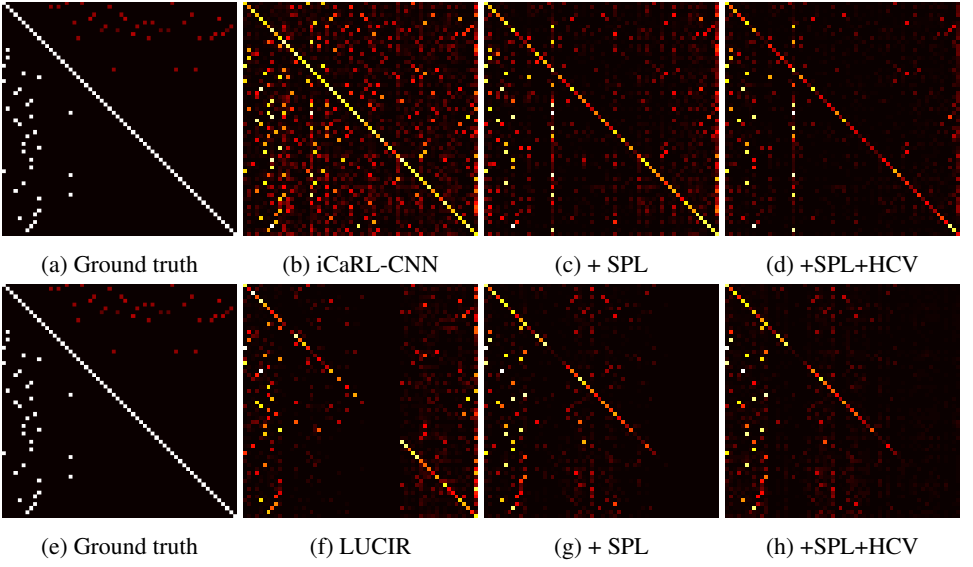(e) Ground truth   (f) LUCIR   (g) + SPL   (h) +SPL+HCV

Figure 7: Confusion matrices of groundtruth, original continual learning methods, applying SPL and applying Infer-HCV after task 11 under IIRC-2-CIFAR setup. The first row is obtained with iCaRL-CNN as the base method and the second row is based on LUCIR.

(a) Ground truth   (b) iCaRL-CNN   (c) + SPL   (d) + SPL + Infer-HCV

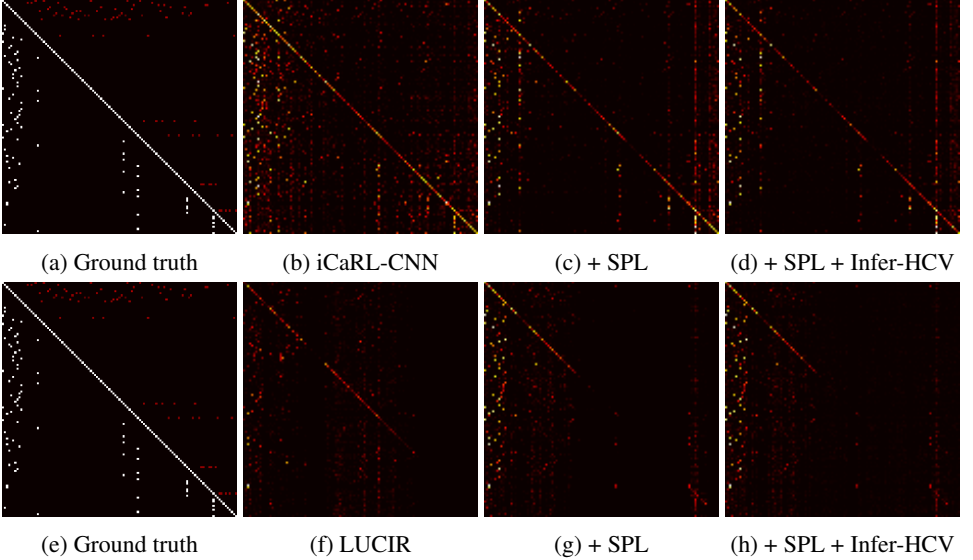(e) Ground truth   (f) LUCIR   (g) + SPL   (h) + SPL + Infer-HCV

Figure 8: Confusion matrices of groundtruth, original continual learning methods, applying SPL and applying Infer-HCV after the last task under IIRC-2-CIFAR setup. The first row is obtained with iCaRL-CNN as the base continual learning method and the second row is based on LUCIR.
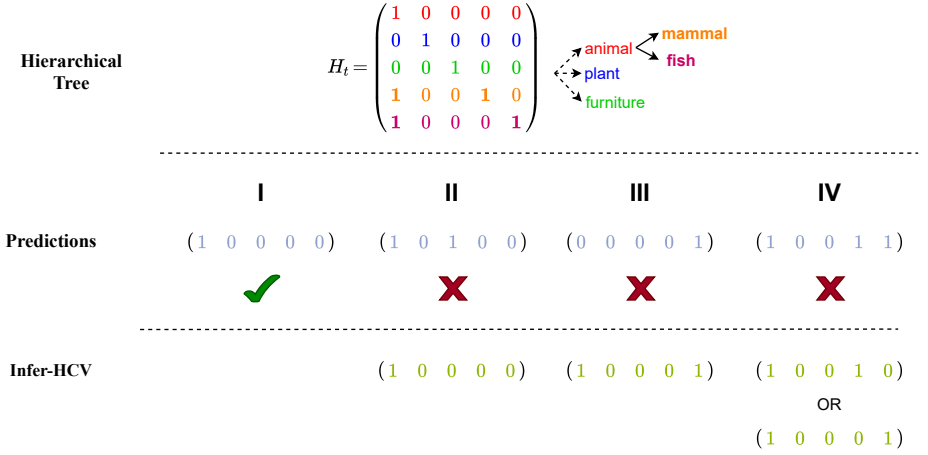
Figure 9: Examples Illustration of Infer-HCV procedure.

3 Groundtruth hierarchies and task splits

Here we show the groundtruth hierarchies of IIRC-2-CIFAR/IIRC-3-CIFAR in Table 1 and IIRC-ImageNet-Subset in Table 2. For the task splits used in our experiments, we select one from the IIRC paper for IIRC-2-CIFAR (Table 3) and propose our splits for IIRC-3-CIFAR (Tab. 4)/IIRC-ImageNet-Subset (Tab. 5) to test the models in more complex hierarchies.

4 Experimental results for IIRC-ImageNet-full

In Fig. 10 we show results for the first 20 tasks (out of 35 in total)[1] for LUCIR and iCaRL-CNN. Our HCV improves by 4.2% for LUCIR and 1.9% for iCaRL-CNN after 20 tasks.
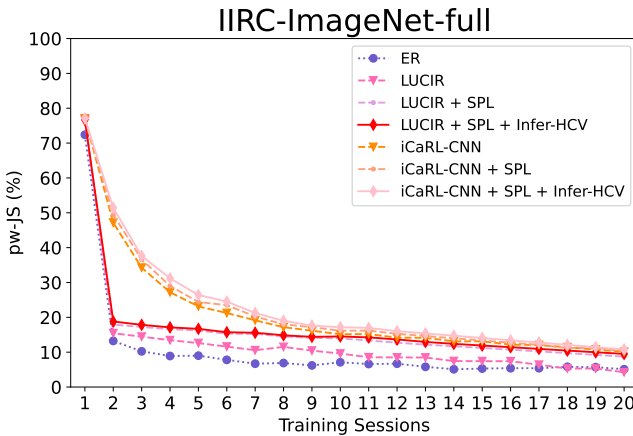

Figure 10: Experiments for IIRC-ImageNet-full.

[1]Because of the demanding computational resources required for this experiment we were only able to compute results until task 20.

rootclass	superclass	subclasses
animals	aquatic mammals	beaver,dolphin,otter,seal,whale
	fish	aquarium fish,flatfish,ray,shark,trout
	insects	bee,beetle,butterfly,caterpillar,cockroach
	large carnivores	leopard,lion,tiger,wolf
	large omnivores and herbivores	bear,camel,cattle,chimpanzee,elephant,kangaroo
	medium sized mammals	fox,porcupine,possum,raccoon,skunk
	reptiles	crocodile,dinosaur,lizard,snake,turtle
	small mammals	hamster,mouse,rabbit,shrew,squirrel
plants	flowers	orchid,poppy,rose,sunflower,tulip
	fruit and vegetables	apple,orange,pear,sweet pepper
	trees	maple tree,oak tree,palm tree,pine tree,willow tree
-	vehicles	bicycle,bus,motorcycle,pickup truck, train,streetcar,tank,tractor
	household furniture	bed,chair,couch,table,wardrobe
	food containers	bottle,bowl,can,cup,plate
	people	baby,boy,girl,man,woman
-	-	mushroom,clock,keyboard,lamp,telephone, television,bridge,castle,house,road, skyscraper,cloud,forest,mountain,plain, sea,crab,lobster,snail,spider,worm,lawn mower,rocket

Table 1: IIRC-2-CIFAR and IIRC-3-CIFAR Hierarchies. IIRC-2-CIFAR is without the root-classes.

superclass	subclasses
primate	Madagascar cat, indri, gibbon, siamang, orangutan, gorilla, chimpanzee, marmoset, capuchin, howler monkey,titi, spider monkey, squirrel monkey, guenon, patas, baboon, macaque, langur, colobus, proboscis monkey
car	ambulance, beach wagon, cab, convertible, jeep, limousine, Model T, racer, sports car, minivan, grille, golfcart
ball	baseball, basketball, croquet ball, golf ball, ping-pong ball, punching bag, rugby ball, soccer ball, tennis ball, volleyball
crustacean	isopod, crayfish, hermit crab, spiny lobster, American lobster, Dungeness crab, rock crab, fiddler crab, king crab
weapon	bow, projectile, cannon, missile, rifle, revolver, assault rifle, holster bison,
spider	black and gold garden spider, barn spider, garden spider, black widow, tarantula, wolf spider, spider web
box	carton, chest, crate, mailbox, pencil box, safe
bag	backpack, mailbag, plastic bag, purse, sleeping bag
beverage	espresso, red wine, cup, eggnog
keyboard	computer keyboard, space bar, typewriter keyboard
-	African crocodile, American alligator, triceratops, trilobite, harvestman, scorpion, tick, centipede, tusker, echidna, platypus, jellyfish, sea anemone, brain coral, flatworm, nematode

Table 2: IIRC-ImageNet-Subset Hierarchy

Task ID	Classes
1	flowers (S), small mammals (S), trees (S), aquatic mammals (S), fruit and vegetables (S), people (S), food containers (S), vehicles (S), large carnivores (S), insects (S)
2	television, spider, shrew, mountain, hamster
3	road, poppy, household furniture (S), woman, bee
4	tulip, clock, orange, beaver, rocket
5	bicycle, can, squirrel, wardrobe, bus
6	whale, sweet pepper, telephone, leopard, bowl
7	skyscraper, baby, cockroach, boy, lobster
8	motorcycle, forest, tank, orchid, chair
9	crab, girl, keyboard, otter, bed
10	butterfly, lawn mower, snail, caterpillar, wolf
11	pear, tiger, pickup truck, cup, reptiles (S)
12	train, sunflower, beetle, apple, palm tree
13	plain, large omnivores and herbivores (S), rose, tractor, crocodile
14	mushroom, couch, lamp, mouse, bridge
15	turtle, willow tree, man, lizard, maple tree
16	lion, elephant, seal, sea, dinosaur
17	worm, bear, castle, plate, dolphin
18	medium sized mammals (S), streetcar, bottle, kangaroo, snake
19	house, chimpanzee, raccoon, porcupine, oak tree
20	pine tree, possum, skunk, fish (S), fox
21	cattle, ray, aquarium fish, cloud, flatfish
22	rabbit, trout, camel, table, shark

Table 3: IIRC-2-CIFAR task split configuration. (S) denotes the super classes.

Task ID	Classes
1	**animals (R)**, food containers **(S)**, house, road, telephone, lamp, rocket
2	fish **(S)**, crab, snail, mushroom, bottle
3	reptiles **(S)**, sea, trout, can, clock
4	vehicles **(S)**, flatfish, snake, aquarium fish, mountain
5	large omnivores and herbivores **(S)**, plate, cup, television, ray
6	small mammals **(S)**, camel, bicycle, keyboard, lawn mower
7	household furniture **(S)**, shark, turtle, spider, forest
8	aquatic mammals **(S)**, couch, kangaroo, streetcar, lobster
9	insects **(S)**, tank, plain, motorcycle, whale
10	large carnivores **(S)**, bear, crocodile, dinosaur, otter
11	**plants (R)**, medium sized mammals **(S)**, tractor, table, bowl
12	fruit and vegetables **(S)**, chimpanzee, cloud, raccoon, butterfly
13	flowers **(S)**, bus, shrew, wardrobe, apple
14	people **(S)**, mouse, skunk, caterpillar, castle
15	trees **(S)**, fox, cockroach, worm, squirrel
16	palm tree, oak tree, lizard, maple tree, orchid
17	rose, bed, train, elephant, sweet pepper
18	skyscraper, beetle, boy, pine tree, lion
19	hamster, pear, bee, man, tiger
20	seal, poppy, porcupine, dolphin, tulip
21	orange, wolf, cattle, willow tree, woman
22	bridge, pickup truck, baby, sunflower, girl
23	leopard, rabbit, beaver, possum, chair

Table 4: IIRC-3-CIFAR task split configuration. **(R)** denotes the root classes and **(S)** denotes the super classes.

Task ID	Classes
1	car **(S)**, box **(S)**, brain coral, echidna, American alligator, African crocodile, tusker, jellyfish, sea anemone, tick
2	bag **(S)**, crustacean **(S)**, trilobite, ambulance, triceratops, sports car, mailbox, grille, nematode, limousine
3	weapon **(S)**, pencil box, jeep, Model T, purse, mailbag, hermit crab, centipede, beach wagon, fiddler crab
4	beverage **(S)**, safe, minivan, scorpion, assault rifle, harvestman, missile, sleeping bag, holster, projectile
5	keyboard **(S)**, revolver, Dungeness crab, American lobster, king crab, cab, convertible, racer, isopod, chest
6	ball **(S)**, backpack, cannon, crayfish, rock crab, espresso, platypus, flatworm, rifle, space bar
7	spider **(S)**, spiny lobster, volleyball, punching bag, carton, golfcart, plastic bag, golf ball, eggnog, baseball
8	primate **(S)**, black widow, basketball, typewriter keyboard, bow, tarantula, garden spider, rugby ball, cup, black and gold garden spider
9	wolf spider, marmoset, squirrel, monkey, guenon, orangutan, macaque, baboon, Madagascar cat, capuchin, soccer ball
10	howler monkey, siamang, gibbon, gorilla, spider web, red wine, crate, colobus, tennis ball, barn spider
11	croquet ball, indri, chimpanzee, titi, spider monkey, langur, ping-pong ball, computer keyboard, patas, proboscis monkey

Table 5: IIRC-ImageNet-Subset task split configuration. **(S)** denotes the super classes.