

3D Object Representations for Fine-Grained Categorization: Supplementary Material

Jonathan Krause¹, Michael Stark^{1,2}, Jia Deng¹, and Li Fei-Fei¹

¹Computer Science Department, Stanford University

²Max Planck Institute for Informatics

1. car-197 and BMW-10 class lists

In Tab. 1 we give the classes and number of images in each class for BMW-10. In Tab. 2 we do the same for car-197. A coarse category distribution for car-197 is given in Fig. 1. The training and test splits for each dataset are fixed and have equal size.

Class	Num. Images
BMW 3 Series Sedan 2007	53
BMW 3 Series Sedan 2009	53
BMW 3 Series Sedan 2012	50
BMW 5 Series Sedan 2007	50
BMW 5 Series Sedan 2008	52
BMW 5 Series Sedan 2011	50
BMW M3 Sedan 2008	51
BMW M5 Sedan 2007	52
BMW ActiveHybrid 5 Sedan 2011	50
BMW Alpina B7 Sedan 2011	51

Table 1: Class list and image count for BMW-10

2. Additional Experimental Details

Here we give additional experimental details for the categorization experiments. Details already given in the main text are not repeated here.

As input into our 3D geometry classifier, we extracted HOG [1] features on a fixed grid of size 340×192 with a spacing of 16 pixels. We use the implementation of HOG given by [3]. The 3D geometry classifier was trained using an L_2 -regularized, L_2 -loss SVM from the LibLinear library [2]. The values of C used were $10^{-6}, 10^{-5}, \dots, 10^3$. The C value used was selected based on minimizing 0-1 error with respect to getting the azimuth prediction within 30 degrees of the ground truth azimuth on BMW-10, where azimuths were hand-annotated. For each geometry (CAD model) hy-

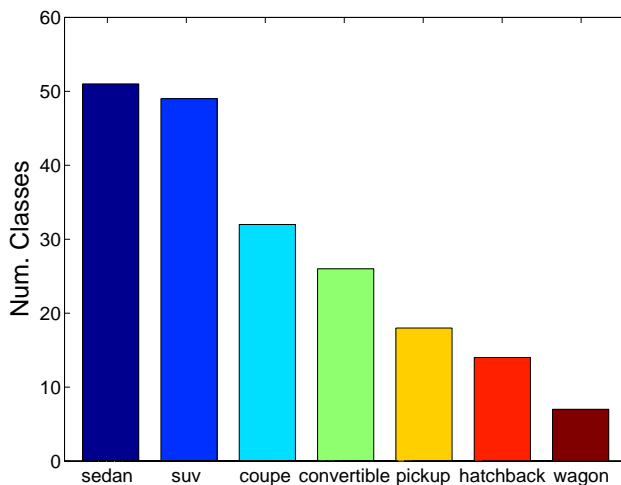


Figure 1: The distribution of coarse types in car-197.

pothesis, 4k patches were extracted on car-types, 2k patches were extracted on BMW-10, and 1k patches were extracted on car-197. All extracted patches were selected to be visible based on the predicted viewpoint. Patches for which the dot product of the patch normal vector and the vector from the patch center to the camera exceeds a fixed threshold of 0.15 were not selected. The projection of each 3D patch was rectified to the size 36×36 , though patches which were not entirely visible (*e.g.* due to being near the edge of the image and therefore potentially cut off) were only rectified to fill as much of the 36×36 patch as is visible. If enough (50%) of the 3D patch’s projection were not visible, however, the patch was similarly not selected. Thus each of the extracted patches is visible from a clean viewing angle.

We use the VLFeat[5] implementation of SIFT [4], using a piecewise-flat windowing function, which dramatically speeds up descriptor computation. For BMW-10 and car-197, descriptors are computed on the rectified patches

Class	Num. Images	Class	Num. Images	Class	Num. Images
AM General Hummer SUV	89	Chevrolet Malibu Hybrid Sedan 2010	77	Hyundai Tucson SUV 2012	87
Acura RL Sedan 2012	64	Chevrolet TrailBlazer SS 2009	80	Hyundai Veracruz SUV 2012	84
Acura TL Sedan 2012	86	Chevrolet Silverado 2500HD Regular Cab 2012	76	Hyundai Sonata Hybrid Sedan 2012	67
Acura TL Type-S 2008	84	Chevrolet Silverado 1500 Classic Extended Cab 2007	85	Hyundai Elantra Sedan 2007	84
Acura TSX Sedan 2012	81	Chevrolet Express Van 2007	70	Hyundai Accent Sedan 2012	48
Acura Integra Type R 2001	89	Chevrolet Monte Carlo Coupe 2007	90	Hyundai Genesis Sedan 2012	87
Acura ZDX Hatchback 2012	78	Chevrolet Malibu Sedan 2007	89	Hyundai Sonata Sedan 2012	79
Aston Martin V8 Vantage Convertible 2012	90	Chevrolet Silverado 1500 Extended Cab 2012	87	Hyundai Elantra Touring Hatchback 2012	85
Aston Martin V8 Vantage Coupe 2012	82	Chevrolet Silverado 1500 Regular Cab 2012	88	Hyundai Azera Sedan 2012	84
Aston Martin Virage Convertible 2012	66	Chrysler Aspen SUV 2009	87	Infiniti G Coupe IPL 2012	68
Aston Martin Virage Coupe 2012	76	Chrysler Sebring Convertible 2010	81	Infiniti QX56 SUV 2011	65
Audi RS 4 Convertible 2008	73	Chrysler Town and Country Minivan 2012	75	Isuzu Ascender SUV 2008	80
Audi A5 Coupe 2012	82	Chrysler 300 SRT-8 2010	97	Jaguar XK XKR 2012	93
Audi TTS Coupe 2012	85	Chrysler Crossfire Convertible 2008	86	Jeep Patriot SUV 2012	88
Audi R8 Coupe 2012	86	Chrysler PT Cruiser Convertible 2008	90	Jeep Wrangler SUV 2012	86
Audi V8 Sedan 1994	87	Daewoo Nubira Wagon 2002	90	Jeep Liberty SUV 2012	89
Audi 100 Sedan 1994	81	Dodge Caliber Wagon 2012	81	Jeep Grand Cherokee SUV 2012	90
Audi 100 Wagon 1994	85	Dodge Caliber Wagon 2007	84	Jeep Compass SUV 2012	85
Audi TT Hatchback 2011	81	Dodge Caravan Minivan 1997	87	Lamborghini Reventon Coupe 2008	72
Audi S6 Sedan 2011	92	Dodge Ram Pickup 3500 Crew Cab 2010	85	Lamborghini Aventador Coupe 2012	87
Audi S5 Convertible 2012	84	Dodge Ram Pickup 3500 Quad Cab 2009	88	Lamborghini Gallardo LP 570-4 Superleggera 2012	71
Audi S5 Coupe 2012	85	Dodge Sprinter Cargo Van 2009	79	Lamborghini Diabolo Coupe 2001	89
Audi S4 Sedan 2012	79	Dodge Journey SUV 2012	88	Land Rover Range Rover SUV 2012	85
Audi S4 Sedan 2007	90	Dodge Dakota Crew Cab 2010	82	Land Rover LR2 SUV 2012	85
Audi TT RS Coupe 2012	79	Dodge Dakota Club Cab 2007	77	Lincoln Town Car Sedan 2011	78
BMW ActiveHybrid 5 Sedan 2012	68	Dodge Magnum Wagon 2008	80	MINI Cooper Roadster Convertible 2012	73
BMW 1 Series Convertible 2012	71	Dodge Challenger SRT8 2011	78	Maybach Landaulet Convertible 2012	58
BMW 1 Series Coupe 2012	82	Dodge Durango SUV 2012	87	Mazda Tribute SUV 2011	72
BMW 3 Series Sedan 2012	85	Dodge Durango SUV 2007	91	McLaren MP4-12C Coupe 2012	88
BMW 3 Series Wagon 2012	83	Dodge Charger Sedan 2012	82	Mercedes-Benz 300-Class Convertible 1993	96
BMW 6 Series Convertible 2007	88	Dodge Charger SRT-8 2009	84	Mercedes-Benz C-Class Sedan 2012	91
BMW X5 SUV 2007	83	Eagle Talon Hatchback 1998	92	Mercedes-Benz SL-Class Coupe 2009	73
BMW X6 SUV 2012	84	FIAT 500 Abarth 2012	55	Mercedes-Benz E-Class Sedan 2012	87
BMW M3 Coupe 2012	89	FIAT 500 Convertible 2012	67	Mercedes-Benz S-Class Sedan 2012	89
BMW M5 Sedan 2010	82	Ferrari FF Coupe 2012	84	Mercedes-Benz Sprinter Van 2012	82
BMW M6 Convertible 2010	82	Ferrari California Convertible 2012	78	Mitsubishi Lancer Sedan 2012	95
BMW X3 SUV 2012	77	Ferrari 458 Italia Convertible 2012	79	Nissan Leaf Hatchback 2012	84
BMW Z4 Convertible 2012	81	Ferrari 458 Italia Coupe 2012	85	Nissan NV Passenger Van 2012	77
Bentley Continental Supersports Convertible 2012	73	Fisker Karma Sedan 2012	87	Nissan Juke Hatchback 2012	88
Bentley Armae Sedan 2009	78	Ford F-450 Super Duty Crew Cab 2012	83	Nissan 240SX Coupe 1998	92
Bentley Mulsanne Sedan 2011	71	Ford Mustang Convertible 2007	89	Plymouth Neon Coupe 1999	88
Bentley Continental GT Coupe 2012	69	Ford Freestar Minivan 2007	88	Porsche Panamera Sedan 2012	87
Bentley Continental GT Coupe 2007	92	Ford Expedition EL SUV 2009	89	Ram C/V Cargo Van Minivan 2012	82
Bentley Continental Flying Spur Sedan 2007	89	Ford Edge SUV 2012	86	Rolls-Royce Phantom Drophead Coupe Convertible 2012	61
Bugatti Veyron 16.4 Convertible 2009	65	Ford Ranger SuperCab 2011	84	Rolls-Royce Ghost Sedan 2012	77
Bugatti Veyron 16.4 Coupe 2009	87	Ford GT Coupe 2006	91	Rolls-Royce Phantom Sedan 2012	88
Buick Regal GS 2012	70	Ford F-150 Regular Cab 2012	85	Scion xD Hatchback 2012	83
Buick Rainier SUV 2007	85	Ford F-150 Regular Cab 2007	90	Smart fortwo Convertible 2012	80
Buick Verano Sedan 2012	75	Ford Focus Sedan 2007	90	Spyker C8 Convertible 2009	90
Buick Enclave SUV 2012	84	Ford E-Series Wagon Van 2012	75	Spyker C8 Coupe 2009	85
Cadillac CTS-V Sedan 2012	86	Ford Fiesta Sedan 2012	85	Suzuki Aerio Sedan 2007	76
Cadillac SRX SUV 2012	82	GMC Terrain SUV 2012	83	Suzuki Kizashi Sedan 2012	92
Cadillac Escalade EXT Crew Cab 2007	89	GMC Savana Van 2012	66	Suzuki SX4 Hatchback 2012	84
Cadillac Silverado 1500 Hybrid Crew Cab 2012	80	GMC Yukon Hybrid SUV 2012	85	Suzuki SX4 Sedan 2012	81
Chevrolet Corvette Convertible 2012	79	GMC Acadia SUV 2012	89	Tesla Model S Sedan 2012	77
Chevrolet Corvette ZR1 2012	93	GMC Canyon Extended Cab 2012	80	Toyota Sequoia SUV 2012	77
Chevrolet Corvette Ron Fellows Edition Z06 2007	75	GMC Savana Cargo Van 2012	70	Toyota Camry Sedan 2012	87
Chevrolet Traverse SUV 2012	88	Geo Metro Convertible 1993	89	Toyota Corolla Sedan 2012	87
Chevrolet Camaro Convertible 2012	89	HUMMER H3T Crew Cab 2010	78	Toyota 4Runner SUV 2012	81
Chevrolet HHR SS 2010	73	HUMMER H2 SUT Crew Cab 2009	87	Volkswagen Golf Hatchback 2012	86
Chevrolet Impala Sedan 2007	86	Honda Odyssey Minivan 2012	84	Volkswagen Golf Hatchback 1991	92
Chevrolet Tahoe Hybrid SUV 2012	74	Honda Odyssey Minivan 2007	82	Volkswagen Beetle Hatchback 2012	85
Chevrolet Sonic Sedan 2012	88	Honda Accord Coupe 2012	78	Volvo C30 Hatchback 2012	83
Chevrolet Express Cargo Van 2007	59	Honda Accord Sedan 2012	77	Volvo 240 Sedan 1993	91
Chevrolet Avalanche Crew Cab 2012	90	Hyundai Veloster Hatchback 2012	82	Volvo XC90 SUV 2007	86
Chevrolet Cobalt SS 2010	83	Hyundai Santa Fe SUV 2012	84		

Table 2: Class list and image count for car-197

every 4 pixels with a patch size of 16. For car-types, descriptors are extracted every 2 pixels with a patch size of 16.

Pooled features for SPM and the SPM-3D methods are L_2 -normalized for all datasets, as is standard. On BMW-10 and car-types, features for BB and BB-3D are normalized to zero mean and unit variance. For car-197, features for all methods are normalized to fit in the range $[-1, 1]$, which we have found can substantially improve SVM training time.

References

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