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# Supplementary Material for Rel3D: A Minimally Contrastive Benchmark for Grounding Spatial Relations in 3D

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## 1 Predicate Vocabulary

There are in total 27336 images in Rel3D. Figure. 1 plots the number of images per predicate.

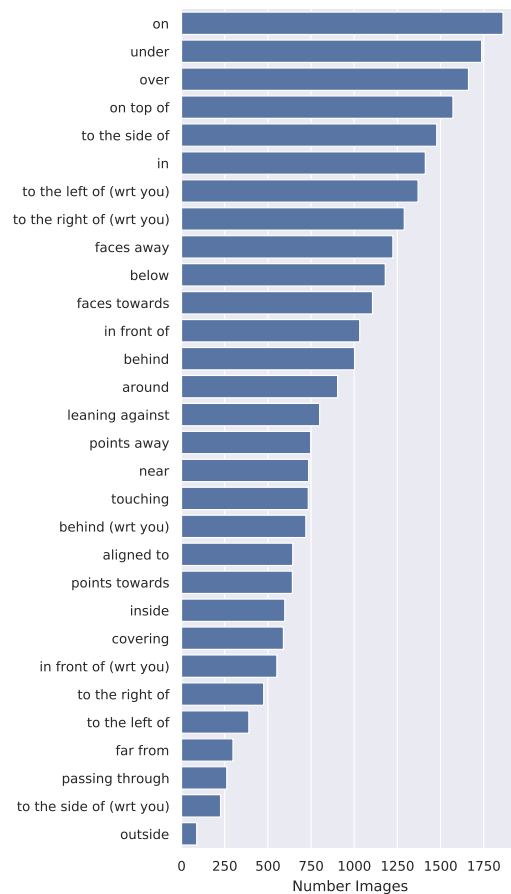


Figure 1: Number of images per predicate in Rel3D

## 2 Object Vocabulary

Table 1: Object categories in Rel3D along with their source.

ShapeNetSem Only	YCB Only	Both in YCB and ShapeNetSem	SimpleWord
Speaker	Can	Cereal Box	Building
Computer	Fruits	Bottle	Mountain
Picture Frame	Cup		Glasses
Desk	Block		Radio
TV	Ball		Stick
Mirror			Stone
Person			House
Picture			Wheel
Book			Shoe
Chair			Door
Rug			Tire
Bed			Tree
Camera			Wall
Media Storage			Bag
Table			
Plant			
Gun			
CellPhone			
Plate			
Cat			
Controller			
Knife			
Cap			
Animal			
Clock			
Ladder			
Car			
Washer			
Bus			
Boat			
Fish			
Ring			
Truck			
Bird			
Teapot			
Airplane			
Bowl			
Fork			
Spoon			
Couch			
Child Bed			
Vase			
Toilet			
Sink			
Suitcase			
Bike			

Table 2: Mapping between categories in ShapeNetSem and Rel3D. All categories in ShapeNetSem not present in Rel3D either have few shapes or have spatial relations similar to some category in Rel3D.

ShapeNetSem Cat.	In Rel3D	< 5 shapes	Rel3D Cat.	Similar Cat. in Rel3D
WallArt	Yes		Picture	
Chair,Recliner	Yes		Chair	
Speaker	Yes		Speaker	
Lamp,DeskLamp	No			Plant
Chair,OfficeChair	Yes		Chair	
Chair,rankChairs,OfficeSideChair	Yes		Chair	
Computer	Yes		Computer	
Chair,rankChairs	Yes		Chair	
Table,RoundTable,AccentTable	Yes		Table	
Picture Frame	Yes		Picture Frame	
Couch	Yes		Couch	
Candle	No			Bottle
Dresser,ChestOfDrawers	Yes		Media Storage	
Desk	Yes		Desk	
Helicopter	Yes		Airplane	
Bottle,WineBottle	Yes		Bottle	
Clock,StandingClock	Yes		Clock	
Bench	Yes		Table	
TV	Yes		TV	
Mirror	Yes		Mirror	
Person	Yes		Person	
Picture	Yes		Picture	
Bottle	Yes		Bottle	
Shelves,Bookcase	Yes		Media Storage	
TrashBin	No			Cup
Bed,LoftBed	No		Bed	
Books	Yes		Book	
Chair,OfficeSideChair	Yes		Chair	
Book	Yes		Book	
Chair	Yes		Chair	
Lamp,FloorLamp	No			Plant
Laptop,Computer	Yes		Computer	
FoodItem,MilkCarton	Yes		Cereal Box	
Oven,Counter	No	Yes		Washer
Fireplace	No			
Lamp,TableLamp	No			Plant
Rug	Yes		Rug	
ArcadeMachine	No	Yes		
Monitor	Yes		TV	
LightSwitch	No			Block
OutdoorTable	Yes		Table	
Bed	Yes		Bed	
Chair,rankChairs,OfficeChair	Yes		Chair	
Table,AccentTable	Yes		Table	
Camera	Yes		Camera	
Media Storage	Yes		Media Storage	
Table	Yes		Table	
Plant	Yes		Plant	
Gun	Yes		Gun	
Dresser,ChestOfDrawers,DresserWithMirror	Yes		Media Storage	
Child Bed	Yes		Child Bed	
Cabinet	Yes		Media Storage	
Vase	Yes		Vase	
Cabinet,Sideboard	Yes		Media Storage	
Chair,Recliner,rankChairs	Yes		Chair	

Lamp,WallLamp	No			Plant
TvStand,Media Storage	Yes		Media Storage	
Window	No			Picture
Stapler	No			Block
Microwave	No			Washer
Violin	No			Knife
TvStand,MediaStorage	Yes		Media Storage	
Table,DiningTable	Yes		Table	
Table,RoundTable	Yes		Table	
CellPhone	Yes		CellPhone	
Chair,SideChair	Yes		Chair	
Plate	Yes		Plate	
Teapot	Yes		Teapot	
Cat	Yes		Cat	
Lamp,CeilingLamp	No			Plant
Controller	Yes		Controller	
Armoire,ChestOfDrawers	Yes		Media Storage	
Chair,ChairWithOttoman	Yes		Chair	
Lamp,LampPost	No			Plant
Armoire,Dresser,Wardrobe,ChestOfDrawers	Yes		Media Storage	
Armoire,Wardrobe,ChestOfDrawers	Yes		Media Storage	
Picture Frame	Yes		Picture Frame	
Bookcase	Yes		Media Storage	
Oven	No			Washer
Refrigerator	No			Washer
Table,EndTable	Yes		Table	
Table,RoundTable,DiningTable	Yes		Table	
Lamp,DeskLamp,FloorLamp	No			Plant
Piano	No			Table
Bathtub	No	Yes		
Stool	Yes		Table	
Whiteboard	No		Picture	
Knife	Yes		Knife	
Lamp	No			Plant
Donut,FoodItem	No			Ring
Cap	Yes		Cap	
GameTable	Yes		Table	
Chair,Couch	Yes		Chair	
ChestOfDrawers	Yes		Media Storage	
Table,EndTable,RoundTable	Yes		Table	
Table,CoffeeTable	Yes		Table	
MediaPlayer	No			Washer
MousePad	No	Yes		
Animal	Yes		Animal	
Picture,Painting	Yes		Picture	
Airplane	Yes		Airplane	
Toilet	Yes		Toilet	
Chair,AccentChair	Yes		Chair	
FoodItem	No	Yes		
Computer	Yes		Computer	
Printer	No			Washer
DartBoard	No			WallArt
Curtain	No			Door
Booth	No	Yes		
SpaceShip	Yes		Airplane	
Horse	Yes		Animal	

Nightstand,ChestOfDrawers	Yes		Media Storage	
Tank	No			Truck
FileCabinet	Yes		Media Storage	
Bed,PosterBed	Yes		Bed	
Cabinet,CurioCabinet	Yes		Media Storage	
Table,RoundTable,CoffeeTable	Yes		Table	
Sink	Yes		Sink	
Ipod	Yes		CellPhone	
Bed,SingleBed	Yes		Bed	
Animal,PlushToy	Yes		Animal	
ToyFigure	No			Block, Person
Bed,KingBed	Yes		Bed	
TvStand	No	Yes		
Notepad	Yes		Book	
Dryer	Yes		Washer	
WallArt,Painting	Yes		Picture	
Bottle,BeerBottle	Yes		Bottle	
NintendoDS,VideoGameController	Yes		Controller	
BarTable	Yes		Table	
Bowl	Yes		Bowl	
Chair,Chaise,rankChairs	Yes		Chair	
Clock	Yes		Clock	
Stool,Barstool	Yes		Table	
Toy	No	Yes		
Clock,WallClock	Yes		Clock	
Rock	Yes		Stone	
Bottle,DrinkBottle	Yes		Bottle	
Dart	No	Yes		
Fork	Yes		Fork	
Cabinet,FileCabinet	No		Media Storage	
CoffeeMaker	No			Sink
DresserWithMirror	Yes		Mirror	
Ladder	Yes		Ladder	
Chair,Chaise	Yes		Chair	
Poster,WallArt	Yes		Picture	
Couch,Loveseat	Yes		Couch	
Chair,BeanBag	Yes		Chair	
Suitcase	Yes		Suitcase	
Wii,VideoGameConsole	Yes		Controller	
Dog	Yes		Animal	
PianoKeyboard	No			Controller, Block
PSP,VideoGameController	Yes		Controller	
Snowman	No	Yes		
Cabinet,Sideboard,CurioCabinet	No	Yes		
Dishwasher	Yes		Washer	
Spoon	Yes		Spoon	
Horse,ToyFigure	Yes		Animal	
Radio	Yes		Radio	
Car	Yes		Car	
FoodItem,Cereal Box	Yes		Cereal Box	
Painting	Yes		Picture	
Washer	Yes		Washer	
Bus	Yes		Bus	
Bed,DoubleBed	Yes		Bed	
Cereal Box	Yes		Cereal Box	
ComputerMouse	Yes			

ToyFigure,SpaceShip	No			
Bowl,FoodItem	No		Bowl	
SodaCan	Yes		Can	
Boat	Yes		Boat	
Fish	Yes		Fish	
GameTable,RoundTable	Yes		Table	
Coin	No			Plate, Ring
Picture,WallArt,Painting	Yes		Picture	
Airplane,ToyFigure,rankAirplanes	Yes		Airplane	
MediaDiscs	No	Yes		
Ipad	Yes		CellPhone	
Ring	Yes		Ring	
PowerSocket	No	Yes		
Ipod,Cabling	No	Yes		
_StanfordSceneDBModels	No			
Couch,Sectional	Yes		Couch	
Backpack	Yes		Bag	
Truck	Yes		Truck	
Lamp,DeskLamp,TableLamp	No	Yes		
Elephant	Yes		Animal	
Bed	Yes		Bed	
Desk,DraftingTable	Yes		Desk	
Bed,RoundBed	Yes		Bed	
Pen	No	Yes		
Chair,SideChair,rankChairs	Yes		Chair	
Board	Yes		Picture	
Bowl,FruitBowl	Yes		Bowl	
Keyboard	No			Block, Book
Door	Yes		Door	
Chair,rankChairs,AccentChair	Yes		Chair	
ChestOfDrawers,DresserWithMirror	Yes		Media Storage	
Ipod,Headphones	No	Yes		
DiscCase	No	Yes		
Tank,ToyFigure	No	Yes		
Headphones	Yes			
LDesk	No		Desk	
Counter	No		Table	
Nightstand	No	Yes		
Rack,Shelves,CoatRack	Yes		Media Storage	
Sword	Yes		Knife	
Ship	Yes		Boat	
Hanger	No	Yes		
Easel	No	Yes		
Bed,CanopyBed,PosterBed	No		Bed	
Armoire,Wardrobe	No	Yes		
Vanity	No	Yes		
SkateBoard	No	Yes		
Bird	Yes		Bird	
BedWithNightstand	Yes		Bed	
Toy,Clock	Yes		Clock	
Car,ToyFigure	Yes		Car	
Cow	Yes		Animal	
Shelves	Yes		Media Storage	
Camera,DSLRCamera	Yes		Camera	
Bike	Yes		Bike	
Bicycle	Yes		Bike	

Thumbtack	No	Yes		
Picture,WallArt	No		Picture	
Shirt	No	Yes		
_OIMwhitelist	No	Yes		
Rack	No	Yes		
Fries,FoodItem	No	Yes		
Hat	Yes		Cap	
Bowl,FoodItem,FruitBowl	Yes	Yes	Bowl	
Armoire	Yes		Media Storage	
PowerStrip	No	Yes		
Chair,KneelingChair	Yes		Chair	
Harp	No	Yes		
Rack,Shelves	Yes		Media Storage	
Armoire,Dresser,ChestOfDrawers	Yes		Media Storage	
Table,ChestOfDrawers	Yes		Table	
Toy,Horse	Yes	Yes	Animal	
Knife,Utensils	Yes		Knife	
Ipod,CellPhone	Yes		CellPhone	
Gamecube,VideoGameConsole	Yes		Controller	
StaplerWithStaples	No	Yes		
Cabinet,ChestOfDrawers	Yes		Media Storage	
Toy,Truck	Yes		Truck	
Bowl,Plate	Yes		Bowl	
Faucet	Yes	Yes	Sink	
Kettle	Yes		Teapot	
Toy,Animal,PlushToy	Yes		Animal	
VideoGameConsole	Yes		Controller	
Bed,Crib	Yes		Child Bed	
ToiletPaper	No			
WasherDryerSet	Yes		Washer	
Donkey	Yes		Animal	
TissueBox	No	Yes		
RiceCooker	No	Yes		
Credenza	No	Yes		
Bed,KingBed	Yes		Bed	
Plate,FoodItem,FoodPlate	Yes		Plate	
Poster	Yes		Picture	
Shower	No	Yes		
Lectern	No	Yes		
Cassette	No	Yes		
WallArtWithFigurine	Yes		Picture	
Glasses	Yes		Glasses	
TvStand,RoundTable,MediaStorage	Yes		Table	
Xbox,VideoGameConsole	No	Yes		
GuitarStand	No	Yes		
_BAD	No	Yes		
Telephone	No	Yes		
Bed,Cradle	Yes		Child Bed	
Toy,Elephant,PlushToy,ToyFigure	Yes		Animal	
Bidet	No	Yes		
DeskLamp	No			Plant
TV,TvStand	No	Yes		
Radio,Clock	Yes		Clock	
Bed,Dresser,DoubleBed,ChestOfDrawers	Yes		Bed	
Room	No			
Calculator	No			Block, Controller

Toy,Airplane	No		Airplane
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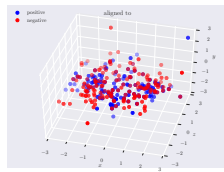
Table 3: Mapping between objects in YCB and Rel3D.

Object ID	Rel3D Category	Reason for not including in Rel3D
001_chips_can	Can	
002_master_chef_can	Can	
003_cracker_box	Cereal Box	
004_sugar_box	Cereal Box	
005_tomato_soup_can	Can	
006_mustard_bottle	Bottle	
007_tuna_fish_can	Can	
008_pudding_box	Cereal Box	
009_gelatin_box	Cereal Box	
010_potted_meat_can	Can	
011_banana	Fruits	
012_strawberry	Fruits	
013_apple	Fruits	
014_lemon	Fruits	
015_peach		Bad reconstruction
016_pear	Fruits	
017_orange	Fruits	
018_plum		Bad reconstruction
019_pitcher_base		Bad reconstruction
021_bleach_cleanser	Bottle	
022_windex_bottle		Largely distorted
023_wine_glass		Missing Object
024_bowl		Bad reconstruction
025_mug	Cup	
026_sponge	Block	
027_skillet		Bad reconstruction
028_skillet_lid		Missing object
029_plate		Bad reconstruction
030_fork		Bad reconstruction
031_spoon		Bad reconstruction
032_knife		Bad reconstruction
033_spatula		Missing object
035_power_drill		Only 1 shape
036_wood_block	Block	
037_scissors		Only 1 shape
038_padlock		Bad reconstruction
039_key		Missing object
040_large_marker		Only 1 shape
041_small_marker		Bad reconstruction
042_adjustable_wrench		Bad reconstruction
043_phillips_screwdriver		Bad reconstruction
044_flat_screwdriver		Bad reconstruction
048_hammer		Only 1 shape
049_small_clamp		Missing .obj file
050_medium_clamp		Bad reconstruction
051_large_clamp		Bad reconstruction
052_extra_large_clamp		Only 1 Shape
053_mini_soccer_ball		Bad reconstruction
054_softball	Ball	
055_baseball	Ball	
056_tennis_ball	Ball	

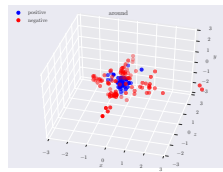


057_racquetball	Ball	
058_golf_ball	Ball	
059_chain		Bad reconstruction
061_foam_brick	Block	
062_dice		Bad reconstruction
063-a_marbles		Bad reconstruction
063-b_marbles		Missing objects
063-c_marbles		Missing objects
063-d_marbles		Missing objects
063-e_marbles		Missing objects
063-f_marbles		Missing objects
065-a_cups		Bad reconstruction, looks like a blob
065-b_cups		Bad reconstruction
065-c_cups		Bad reconstruction
065-d_cups	Cup	
065-e_cups	Cup	
065-f_cups	Cup	
065-g_cups	Cup	
065-h_cups		Bad reconstruction
065-i_cups	Cup	
065-j_cups	Cup	
070-a_colored_wood_blocks		Bad reconstruction
070-b_colored_wood_blocks		Missing objects
071_nine_hole_peg_test	Block	
072-a_toy_airplane		Small Object Part
072-b_toy_airplane		Small Object Part
072-c_toy_airplane		Small Object Part
072-d_toy_airplane		Small Object Part
072-e_toy_airplane		Small Object Part
072-f_toy_airplane		Small Object Part
072-g_toy_airplane		Small Object Part
072-h_toy_airplane		Small Object Part
072-i_toy_airplane		Small Object Part
072-j_toy_airplane		Small Object Part
072-k_toy_airplane		Small Object Part
073-a_lego_duplo		Small Object Part
073-b_lego_duplo		Small Object Part
073-c_lego_duplo		Small Object Part
073-d_lego_duplo		Small Object Part
073-e_lego_duplo		Small Object Part
073-f_lego_duplo		Small Object Part
073-g_lego_duplo		Small Object Part
073-h_lego_duplo		Small Object Part
073-i_lego_duplo		Small Object Part
073-j_lego_duplo		Small Object Part
073-k_lego_duplo		Small Object Part
073-l_lego_duplo		Small Object Part
073-m_lego_duplo		Small Object Part
076_timer		Only 1 shape
077_rubiks_cube	Block	
078_tshirt		No obj model

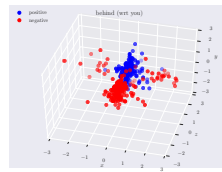
### 3 Relation Plots



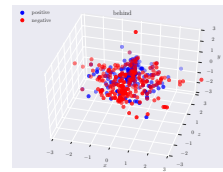
(a) aligned to



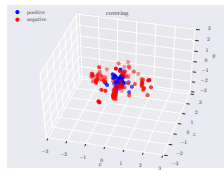
(b) around



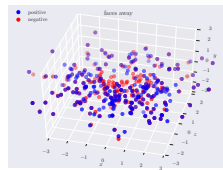
(c) behind (wrt you)



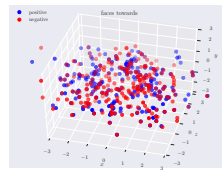
(d) behind



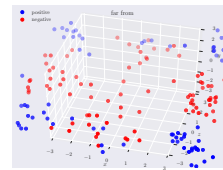
(e) covering



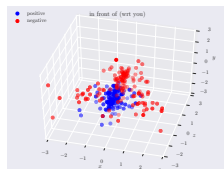
(f) faces away



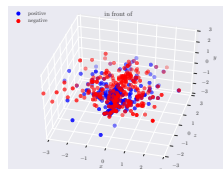
(g) faces towards



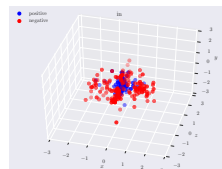
(h) far from



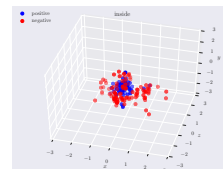
(i) in front of (wrt you)



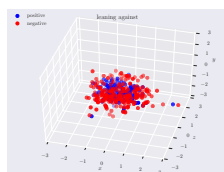
(j) in front of



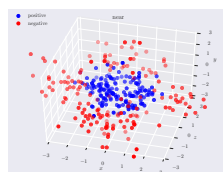
(k) in



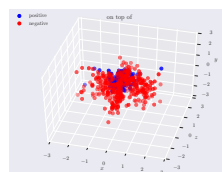
(l) inside



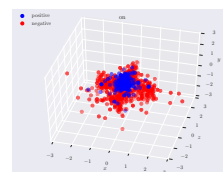
(m) leaning against



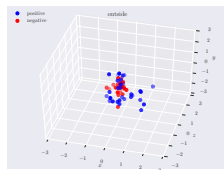
(n) near



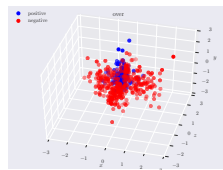
(o) on top of



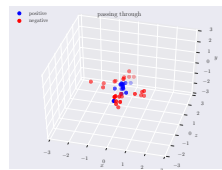
(p) on



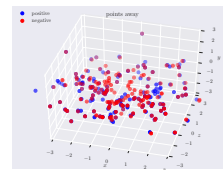
(q) outside



(r) over



(s) passing through



(t) points away

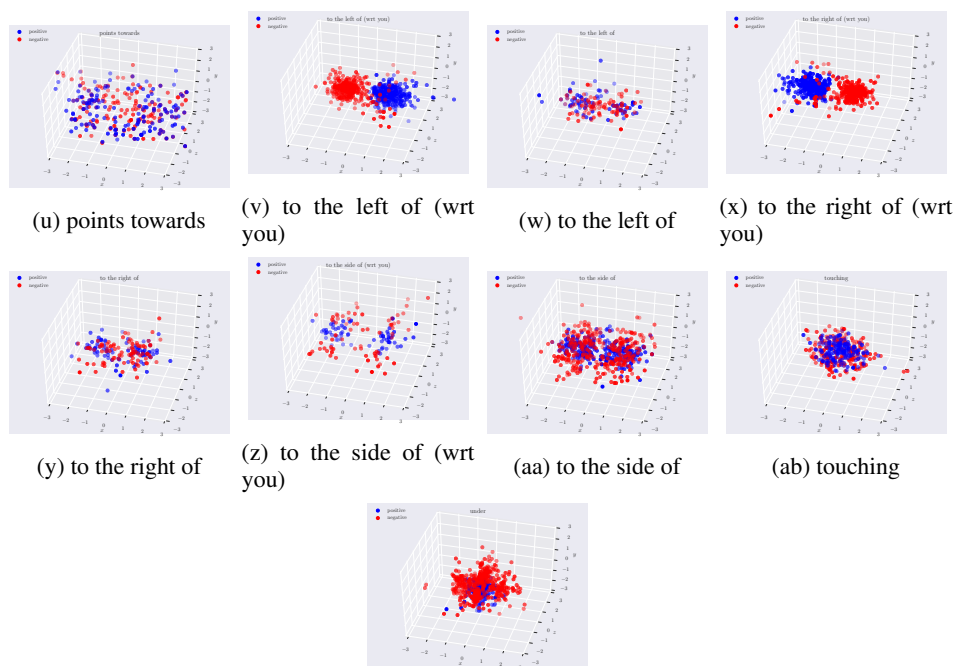


Figure 2: Each dot represents a scene in our dataset (blue means positive examples and red for negative). The location of the dot represent the relative position of the object w.r.t. to the subject in the frame of reference of the observer.

## 4 Model Hyperparameters

Table 4: All the hyper-parameters we used to tune the baseline models in Rel3D. The values in bold represent the hyperparameter choice that performed the best on the validation set.

Model	l2 regularization	Feature dim	Roi size	Back-bone
2D	0, <b>1e-4</b> , 1e-3	64, 128, <b>256</b> , 512		
VtranE	0, 1e-6, <b>1e-4</b> , 1e-2	128, 256, 512, 1024, <b>2048</b> , 4096	1, <b>3</b> , 5	<b>resnet18</b>
VipCNN	<b>0</b> , 1e-6, 1e-4		3, 5, <b>7</b> , 9	<b>resnet18</b> , resnet101
DRNet	0, 1e-6, <b>1e-4</b> , 1e-3	64, <b>128</b> , 256, 512		
PPFRCN	<b>0</b> , 1e-6, 1e-4		<b>3</b>	<b>resnet18</b> , resnet101

## 5 Results Predicate-wise

Model	aligned to	around	around	around (wrt y-z)	around	coverage	faces away	faces towards	far from	in	in front of	in front of (wrt y-z)	inside	leaving against	near	on	on top of	outside	over	passing through	peers away	points towards	to the left of	to the left of (wrt y-z)	to the right of	to the right of (wrt y-z)	to the side of	to the side of (wrt y-z)	touching
2d	0.578	0.817	0.576	0.945	0.845	0.873	0.513	0.5	0.872	0.762	0.625	0.931	0.717	0.757	0.916	0.845	0.831	0.667	0.798	0.67	0.516	0.551	0.717	0.948	0.517	0.935	0.661	0.889	0.674
VtranE	0.612	0.768	0.53	0.961	0.818	0.822	0.526	0.55	0.723	0.766	0.578	0.944	0.692	0.716	0.878	0.849	0.838	0.667	0.805	0.717	0.548	0.543	0.667	0.933	0.542	0.952	0.641	0.792	0.667
VipCNN	0.647	0.774	0.606	0.914	0.75	0.803	0.545	0.567	0.872	0.703	0.602	0.889	0.725	0.662	0.882	0.797	0.77	0.583	0.743	0.594	0.492	0.623	0.5	0.881	0.592	0.917	0.713	0.889	0.727
DRNet	0.612	0.848	0.576	0.961	0.777	0.866	0.539	0.558	0.723	0.752	0.625	0.958	0.75	0.676	0.849	0.832	0.858	0.708	0.775	0.689	0.5	0.529	0.6	0.952	0.475	0.957	0.67	0.875	0.667
PPFRCN	0.647	0.811	0.606	0.844	0.777	0.793	0.513	0.567	0.83	0.752	0.633	0.889	0.7	0.635	0.857	0.828	0.791	0.542	0.741	0.66	0.516	0.601	0.817	0.913	0.558	0.939	0.69	0.903	0.667
MLP (Aligned Absolute)	0.672	0.945	0.803	0.977	0.946	0.904	0.955	0.783	0.787	0.841	0.891	0.944	0.817	0.797	0.929	0.909	0.824	0.792	0.869	0.698	0.913	0.703	0.817	0.956	0.808	0.965	0.796	0.889	0.674
MLP (Raw Absolute)	0.672	0.915	0.682	0.977	0.946	0.889	0.818	0.608	0.862	0.831	0.742	0.903	0.85	0.743	0.933	0.888	0.845	0.833	0.874	0.708	0.786	0.652	0.717	0.94	0.567	0.987	0.716	0.917	0.659
Human	0.888	0.982	0.97	0.961	0.946	0.965	0.968	0.925	0.777	0.955	0.938	0.958	0.933	0.932	0.966	0.983	0.973	0.75	0.982	0.972	0.9682	0.986	0.95	0.988	0.958	0.983	0.951	0.986	0.932