
Supervising Variational Autoencoder Latent Representations with Language

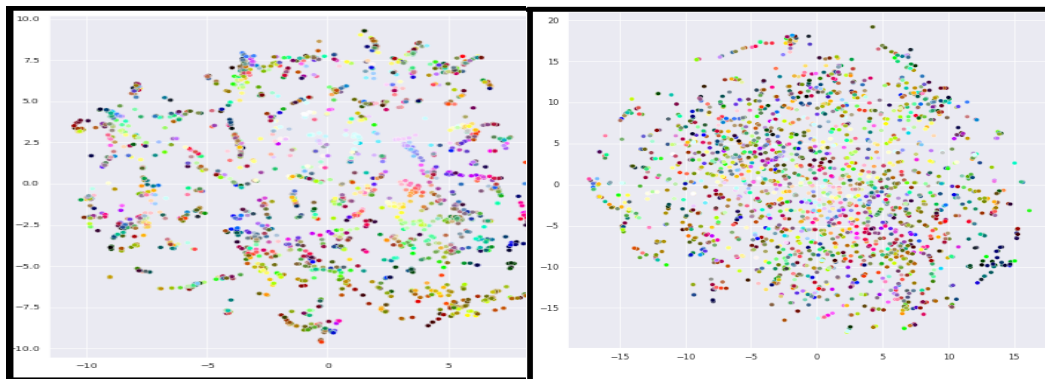
Thomas Lu, Aboli Marathe, Ada Martin*
Machine Learning Department
Carnegie Mellon University
Pittsburgh, PA 15213
ttl, abolim, gamartin@cs.cmu.edu

1 Supplementary Material

1.1 Supplementary Proof for Method 1

$$\begin{aligned}W^\dagger y &= \arg \min_{a \in \mathbb{R}^n} \|a\|_2 : Wa = y \\W^\dagger(y - Wz) &= \arg \min_{a \in \mathbb{R}^n} \|a\|_2 : Wa = y - Wz \\W^\dagger(y - Wz) &= \arg \min_{a \in \mathbb{R}^n} \|(a + z) - z\|_2 : W(a + z) = y - Wz + Wz = y \\z + W^\dagger(y - Wz) &= \arg \min_{a' = a+z \in \mathbb{R}^n} \|a' - z\|_2 : Wa' = y \\z' &= z + W^\dagger(y - Wz)\end{aligned}\tag{1}$$

1.2 Preliminary visualizations of latent embeddings



(a) β VAE with 16 dimensions

(b) β VAE with 64 dimensions

Figure 1: TSNE visualization of latent space colored by shape color, by number of dimensions.

1.3 Extended metric evaluations over models

*Equal Contribution

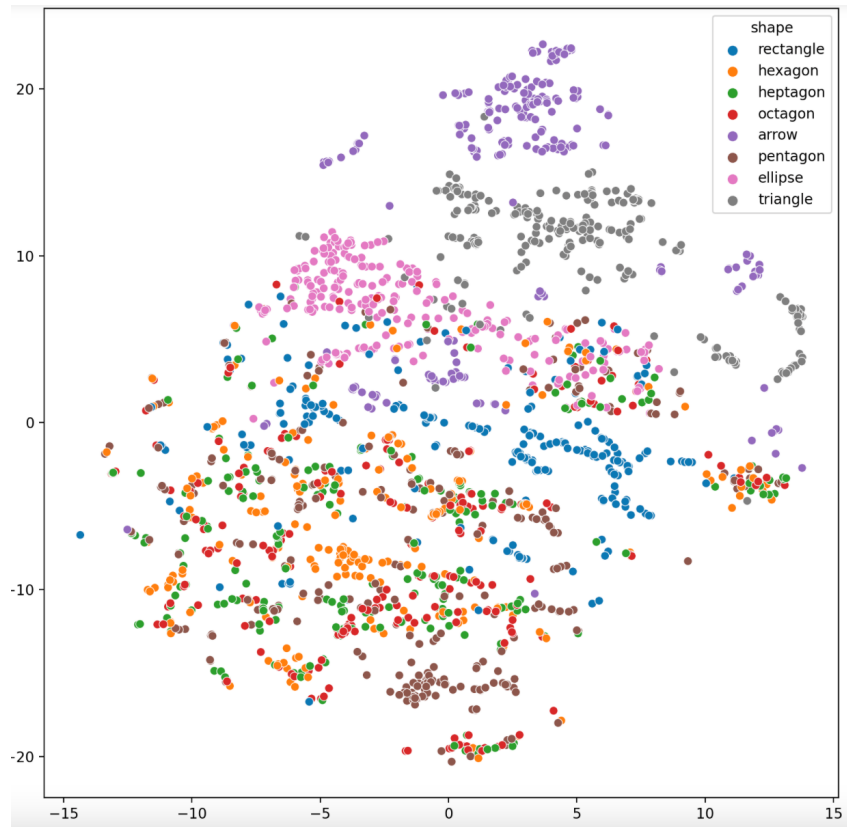
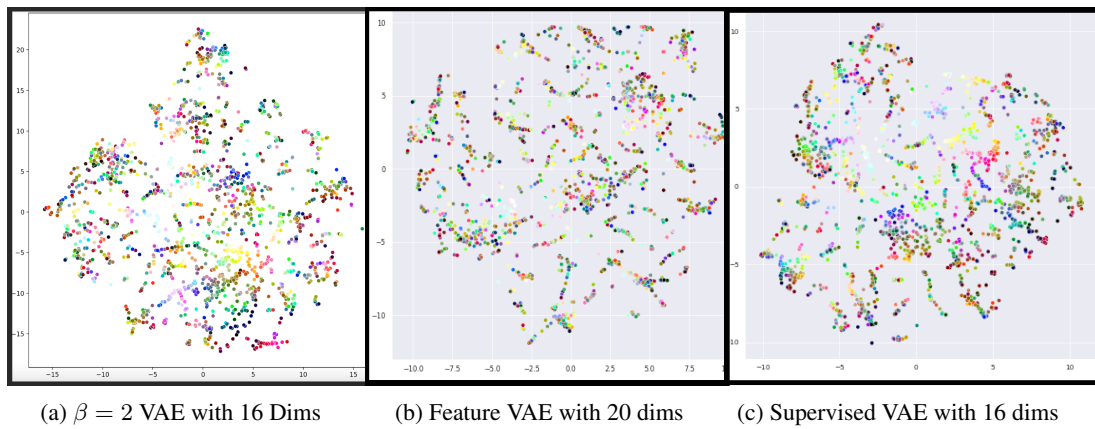


Figure 2: Unsupervised separation of image shape using β -VAE



(a) $\beta = 2$ VAE with 16 Dims (b) Feature VAE with 20 dims (c) Supervised VAE with 16 dims

Figure 3: TSNE Visualization of Learned Dimensions. Color corresponds to actual shape color.

| DeltaE Mean | DeltaE SD | DeltaE Image | ISSM | PSNR | RMSE | SAM | SRE |
|-------------|--------------|--------------|------|------------|-------------|------------|------------|
| 85.37235016 | 10.08097934 | 99.84742892 | 0 | 49.8515353 | 0.003614479 | 89.9269135 | 56.0562656 |
| 83.1538753 | 10.58003476 | 99.82485437 | 0 | 49.7780122 | 0.003652261 | 89.9196728 | 55.6582276 |
| 74.4683015 | 14.67854582 | 99.84049242 | 0 | 48.9800252 | 0.004012294 | 89.8993507 | 55.3675234 |
| 85.94664851 | 9.877941112 | 99.80686107 | 0 | 49.8010974 | 0.00366817 | 89.9241021 | 55.7735479 |
| 86.32947505 | 9.7711538555 | 99.83515507 | 0 | 49.6978318 | 0.003679249 | 89.9228971 | 55.8228983 |
| 80.20088924 | 12.64002768 | 99.83027262 | 0 | 49.3944434 | 0.003793865 | 89.9191679 | 55.66915 |
| 86.0579958 | 9.703918132 | 99.82946992 | 0 | 49.5013837 | 0.003743515 | 89.9289777 | 55.6738099 |
| 86.4979923 | 9.005263062 | 99.85798963 | 0 | 49.4263334 | 0.003796007 | 89.9319512 | 55.6490454 |
| 71.97182606 | 15.63475483 | 99.80565217 | 0 | 48.6277481 | 0.00417896 | 89.8883286 | 55.3863212 |
| 84.74956807 | 10.13846351 | 99.80590224 | 0 | 49.481581 | 0.003749245 | 89.923961 | 55.5893794 |
| 60.06937012 | 15.7285242 | 99.75750149 | 0 | 40.2913431 | 0.010321989 | 89.8647198 | 50.4761237 |
| 76.42245611 | 14.41127921 | 99.86195147 | 0 | 43.6144696 | 0.007297398 | 89.9378975 | 53.3335198 |
| 72.97571105 | 15.37633405 | 99.80285531 | 0 | 48.7055782 | 0.004108393 | 89.8904549 | 55.4997442 |
| 84.9080675 | 10.20154562 | 99.82816937 | 0 | 49.5049134 | 0.003758038 | 89.9236788 | 55.6273476 |
| 81.78028352 | 13.83108305 | 99.8121207 | 0 | 46.2615076 | 0.005258482 | 89.8503094 | 54.3624871 |
| 68.00303234 | 11.64256123 | 99.85992203 | 0 | 32.1135641 | 0.024820503 | 89.7533253 | 45.5666173 |
| 56.77113966 | 18.32302229 | 99.74340707 | 0 | 33.6222522 | 0.020889919 | 89.6125698 | 46.2831413 |
| 83.58569929 | 11.15705586 | 99.84812267 | 0 | 48.3602215 | 0.004291193 | 89.917211 | 55.2330935 |
| 71.526181 | 13.77365616 | 99.805847 | 0 | 42.5239465 | 0.008275347 | 89.8551714 | 51.7165511 |
| 70.12852078 | 10.47354229 | 99.87341213 | 0 | 31.8628598 | 0.025550332 | 89.7613251 | 45.4082945 |
| 81.56852409 | 11.29644737 | 99.83049994 | 0 | 49.4544319 | 0.003769077 | 89.9310637 | 55.5660675 |
| 82.77907348 | 11.33642956 | 99.82355417 | 0 | 49.7594147 | 0.003704068 | 89.9174464 | 55.6439705 |
| 80.62371572 | 12.1397382 | 99.82413363 | 0 | 49.7849496 | 0.003643075 | 89.92519 | 55.6798011 |
| 83.39589952 | 11.05756679 | 99.80731784 | 0 | 49.5303137 | 0.003739166 | 89.9133158 | 55.5566966 |
| 82.1880923 | 10.65432155 | 99.83313186 | 0 | 49.542064 | 0.003758133 | 89.9128161 | 55.4731689 |
| 82.37439744 | 10.82230186 | 99.86094229 | 0 | 49.853025 | 0.003636457 | 89.9123354 | 55.7761112 |
| 83.59522252 | 10.29951058 | 99.82740711 | 0 | 49.7529173 | 0.003678019 | 89.9345317 | 55.6729473 |
| 83.47392538 | 10.22729482 | 99.84211031 | 0 | 49.7125372 | 0.003667407 | 89.9336195 | 55.8118477 |
| 82.92362616 | 10.47881462 | 99.80299206 | 0 | 49.2292911 | 0.003902122 | 89.9300242 | 55.4351552 |
| 82.79425902 | 10.1764228 | 99.86235773 | 0 | 49.1437125 | 0.003899797 | 89.9169738 | 55.2968686 |
| 83.89261009 | 9.661607472 | 99.84756326 | 0 | 49.311892 | 0.003856549 | 89.9384117 | 55.5294328 |
| 84.16734519 | 9.17078972 | 99.82434256 | 0 | 49.0966589 | 0.003960368 | 89.9355564 | 55.2402109 |
| 83.60728788 | 10.04694195 | 99.80967568 | 0 | 48.8714361 | 0.004019313 | 89.9284056 | 55.3100713 |
| 83.53472328 | 9.624552979 | 99.83961905 | 0 | 49.0231678 | 0.003972613 | 89.9172706 | 55.2967717 |
| 81.85317133 | 10.65566666 | 99.81392652 | 0 | 49.2032471 | 0.003863178 | 89.9129361 | 55.4098536 |
| 83.43120867 | 10.00277308 | 99.84195797 | 0 | 49.2303658 | 0.003847364 | 89.9302416 | 55.3974018 |
| 82.55724033 | 10.74949521 | 99.83111474 | 0 | 48.2002218 | 0.004342867 | 89.9237392 | 54.7828745 |
| 84.30204629 | 8.98324916 | 99.88406657 | 0 | 48.6851578 | 0.004101585 | 89.9340629 | 55.2667594 |
| 84.04971278 | 9.246107474 | 99.87597479 | 0 | 48.9716617 | 0.003980993 | 89.916781 | 55.2256914 |
| 81.9128139 | 10.44728756 | 99.8414792 | 0 | 48.5024599 | 0.004239035 | 89.9351674 | 54.990026 |
| 83.81074231 | 9.442337473 | 99.86669217 | 0 | 48.7220626 | 0.004128001 | 89.935219 | 55.3004267 |
| 82.71274473 | 10.13030781 | 99.8333169 | 0 | 48.9084688 | 0.004036403 | 89.9249925 | 55.1899346 |
| 83.10587827 | 9.379876833 | 99.84764896 | 0 | 48.8190908 | 0.004073917 | 89.9208848 | 55.1965744 |
| 83.65421358 | 9.723266418 | 99.85882528 | 0 | 48.4093265 | 0.004243158 | 89.9339769 | 54.9807258 |
| 90.37115455 | 7.418360584 | 99.77583678 | 0 | 50.1251011 | 0.00355265 | 89.9284321 | 55.9303964 |
| 90.10328933 | 6.309393286 | 99.83541721 | 0 | 50.2241919 | 0.003511451 | 89.9235766 | 56.0309087 |
| 89.52706218 | 7.276299712 | 99.8420072 | 0 | 49.8844127 | 0.003622904 | 89.9134433 | 55.8949604 |
| 89.72305891 | 7.172956317 | 99.84004873 | 0 | 50.1325822 | 0.003515362 | 89.9331967 | 55.8719051 |
| 88.2952284 | 7.368274245 | 99.80091653 | 0 | 49.9309887 | 0.003598907 | 89.924944 | 55.8057285 |
| 90.08241524 | 6.588010836 | 99.80243014 | 0 | 49.8660997 | 0.003657172 | 89.9180992 | 55.8722675 |
| 89.22591668 | 6.372500359 | 99.79493399 | 0 | 50.0575994 | 0.003553004 | 89.922742 | 55.8818254 |
| 89.81696833 | 7.668472389 | 99.81830076 | 0 | 49.9047691 | 0.003629408 | 89.9269239 | 55.965862 |
| 89.78290658 | 7.16576802 | 99.83262255 | 0 | 50.1095045 | 0.00354452 | 89.9102722 | 55.8746032 |
| 88.83997104 | 6.685862782 | 99.79291953 | 0 | 49.9840762 | 0.00363976 | 89.9185979 | 55.797489 |
| 89.85167592 | 6.674970591 | 99.82309165 | 0 | 50.2085752 | 0.003528285 | 89.9188932 | 55.9378788 |
| 90.02418347 | 6.680187252 | 99.84534448 | 0 | 49.9837988 | 0.00359679 | 89.9153963 | 55.9759644 |
| 91.0653601 | 6.023944638 | 99.84627143 | 0 | 49.9872892 | 0.003589173 | 89.9324557 | 55.9275397 |
| 90.77638994 | 7.350182592 | 99.79839287 | 0 | 50.1728061 | 0.003530351 | 89.9210182 | 56.0748023 |
| 90.16075003 | 7.347728143 | 99.80066735 | 0 | 50.5847892 | 0.003358945 | 89.9248665 | 56.2606368 |
| 90.51723133 | 6.563730485 | 99.80631589 | 0 | 50.2992494 | 0.003498312 | 89.9140559 | 56.2085245 |
| 90.17792131 | 6.028589534 | 99.77008576 | 0 | 50.3449811 | 0.003449374 | 89.9285483 | 56.0182645 |
| 90.70516304 | 6.332362613 | 99.77231597 | 0 | 50.2961869 | 0.003486292 | 89.9216837 | 56.031732 |
| 90.67590742 | 5.948871225 | 99.80901361 | 0 | 50.4609011 | 0.00338646 | 89.9275496 | 56.1699071 |
| 91.14904941 | 6.874060109 | 99.80146112 | 0 | 50.5281331 | 0.003394589 | 89.9216506 | 56.23837 |
| 90.64280831 | 6.577647162 | 99.7894642 | 0 | 50.6392468 | 0.003336218 | 89.9242612 | 56.1573373 |
| 90.08824106 | 6.27144065 | 99.78683841 | 0 | 49.82965 | 0.003627247 | 89.9171585 | 55.7464598 |

Table 1: Complete set of Feature-VAE Experimentation and Baselines Results with Color Retained.

| ISSM (Color Removed) | PSNR (Color Removed) | RMSE (Color Removed) | SAM (Color Removed) | SRE (Color Removed) |
|----------------------|----------------------|----------------------|---------------------|---------------------|
| 0 | 51.8083778 | 0.003072501 | 89.8392347 | 55.3849825 |
| 0 | 51.6730177 | 0.003106544 | 89.7845747 | 55.3253321 |
| 0 | 50.87473 | 0.003390205 | 89.7792307 | 54.9326052 |
| 0 | 51.6760053 | 0.00312844 | 89.7986223 | 55.3274067 |
| 0 | 51.5567595 | 0.003160337 | 89.8027452 | 55.2693892 |
| 0 | 51.3940379 | 0.003190409 | 89.8119292 | 55.1853055 |
| 0 | 51.2782708 | 0.003226151 | 89.8162759 | 55.1045963 |
| 0 | 51.3169222 | 0.003241428 | 89.8518941 | 55.1445768 |
| 0 | 50.7889024 | 0.003548128 | 89.7978516 | 54.8661933 |
| 0 | 51.4110253 | 0.003171204 | 89.8135443 | 55.2026299 |
| 0 | 41.7715368 | 0.008915974 | 89.8549989 | 50.3644508 |
| 0 | 45.5317557 | 0.006221735 | 89.9142556 | 52.2571097 |
| 0 | 50.8733862 | 0.003466823 | 89.7884575 | 54.9258052 |
| 0 | 51.3734728 | 0.003198978 | 89.8119883 | 55.1709625 |
| 0 | 48.355315 | 0.004472106 | 89.7598862 | 53.6655649 |
| 0 | 32.2323734 | 0.024501369 | 89.7191718 | 45.6102767 |
| 0 | 33.7317606 | 0.020637794 | 89.5302802 | 46.3560814 |
| 0 | 50.1251057 | 0.003712379 | 89.7714176 | 54.5508354 |
| 0 | 44.2547727 | 0.007042995 | 89.8447749 | 51.6205325 |
| 0 | 32.0933641 | 0.024892842 | 89.743341 | 45.5297755 |
| 0 | 51.4372843 | 0.003179414 | 89.8397696 | 55.2010921 |
| 0 | 51.7043592 | 0.003117796 | 89.8067119 | 55.3256388 |
| 0 | 51.8566642 | 0.003065795 | 89.8140155 | 55.4146593 |
| 0 | 51.5197778 | 0.003141671 | 89.7630691 | 55.2515235 |
| 0 | 51.5817887 | 0.003156057 | 89.7828162 | 55.2686212 |
| 0 | 51.922791 | 0.003065559 | 89.7883473 | 55.4583074 |
| 0 | 51.6826813 | 0.003105763 | 89.8412685 | 55.3251902 |
| 0 | 51.6771756 | 0.003094633 | 89.8490542 | 55.3507324 |
| 0 | 51.2114075 | 0.003296588 | 89.7859158 | 55.1060727 |
| 0 | 51.1171951 | 0.003276372 | 89.8073747 | 55.0515677 |
| 0 | 51.3007967 | 0.003253492 | 89.8526892 | 55.1314876 |
| 0 | 51.0278688 | 0.003356372 | 89.8767672 | 54.9887172 |
| 0 | 50.9768238 | 0.003362837 | 89.8228627 | 54.968146 |
| 0 | 51.1569486 | 0.003290175 | 89.8475088 | 55.063016 |
| 0 | 51.2586876 | 0.003231213 | 89.8243795 | 55.1179504 |
| 0 | 51.2928709 | 0.003189202 | 89.8295157 | 55.151943 |
| 0 | 50.0577951 | 0.003687268 | 89.812698 | 54.5176069 |
| 0 | 50.7661087 | 0.003418463 | 89.8646121 | 54.8691297 |
| 0 | 51.1014479 | 0.003312534 | 89.8196671 | 55.0491269 |
| 0 | 50.4600363 | 0.003585644 | 89.8279746 | 54.7220213 |
| 0 | 50.7539234 | 0.00347558 | 89.8598852 | 54.8634467 |
| 0 | 50.9072229 | 0.003397871 | 89.8276551 | 54.9277527 |
| 0 | 50.7850672 | 0.00343669 | 89.7920146 | 54.8758934 |
| 0 | 50.281062 | 0.003602214 | 89.8498167 | 54.6209099 |
| 0 | 51.8560492 | 0.003071448 | 89.8345047 | 55.4186805 |
| 0 | 51.6089209 | 0.003141411 | 89.7626388 | 55.2665953 |
| 0 | 51.6659408 | 0.003099406 | 89.8302721 | 55.3208393 |
| 0 | 51.5713178 | 0.0031364 | 89.8440187 | 55.2842478 |
| 0 | 51.8057082 | 0.003067768 | 89.784467 | 55.3731314 |
| 0 | 51.9678701 | 0.003032022 | 89.7940891 | 55.4705266 |
| 0 | 51.5560288 | 0.003154671 | 89.8255464 | 55.2557315 |
| 0 | 51.7730382 | 0.003100753 | 89.828597 | 55.3634921 |
| 0 | 51.633282 | 0.003133157 | 89.8497108 | 55.3115023 |
| 0 | 51.6519245 | 0.003151673 | 89.7776603 | 55.2999509 |
| 0 | 51.3481212 | 0.003232326 | 89.8270866 | 55.1579352 |
| 0 | 51.3811453 | 0.003187729 | 89.8194454 | 55.1655916 |
| 0 | 51.1682153 | 0.003259374 | 89.7832403 | 55.0590872 |
| 0 | 51.4572189 | 0.003188672 | 89.7938488 | 55.2056876 |
| 0 | 51.4969247 | 0.003180758 | 89.8053244 | 55.2181654 |
| 0 | 51.8393722 | 0.003087912 | 89.8159123 | 55.4096108 |
| 0 | 51.1457992 | 0.003301198 | 89.8360352 | 55.0494315 |
| 0 | 51.318393 | 0.003251849 | 89.7860267 | 55.1549787 |
| 0 | 51.2648502 | 0.003275665 | 89.8397834 | 55.1312173 |
| 0 | 51.3915604 | 0.003227163 | 89.8167082 | 55.180878 |
| 0 | 51.0072536 | 0.003334403 | 89.8412903 | 54.980157 |
| 0 | 51.077624 | 0.003331985 | 89.8339932 | 55.032195 |
| 0 | 51.3524181 | 0.003254772 | 89.8173488 | 55.1630495 |
| 0 | 51.0764555 | 0.003307998 | 89.8477724 | 55.0374579 |
| 0 | 51.546194 | 0.003164405 | 89.8012173 | 55.248444 |
| 0 | 52.2400596 | 0.002921688 | 89.7872134 | 55.6051086 |
| 0 | 52.1846372 | 0.002962261 | 89.8173905 | 55.5811315 |

Table 2: Complete set of Feature-VAE Experimentation and Baselines Results with Color Removed.

| Dimensions | Beta | Embedding | DeltaE Color | DeltaE SD | DeltaE Image | ISSM | PSNR | RMSE | SAM | SRE | Smoothing |
|------------|------|-----------|--------------|-----------|--------------|------|-------|------|-------|-------|-----------|
| 8 | 0.5 | 2 | 48.67 | 18.87 | 99.77 | 0 | 48.27 | 0 | 89.88 | 55.18 | 0.001 |
| 8 | 0.5 | 2 | 43.76 | 19.49 | 99.75 | 0 | 48.19 | 0 | 89.88 | 55.12 | 0.001 |
| 8 | 0.5 | 2 | 42.54 | 17.97 | 99.8 | 0 | 47.99 | 0 | 89.88 | 55.29 | 0.001 |
| 8 | 0.5 | 2 | 56.54 | 15.94 | 99.8 | 0 | 48.32 | 0 | 89.88 | 55.18 | 0.005 |
| 8 | 0.5 | 2 | 56.36 | 15.63 | 99.77 | 0 | 48.28 | 0 | 89.88 | 55.18 | 0.005 |
| 8 | 0.5 | 2 | 49.58 | 17.81 | 99.75 | 0 | 48.2 | 0 | 89.88 | 55.12 | 0.005 |
| 8 | 0.5 | 2 | 47.83 | 18.71 | 99.8 | 0 | 47.99 | 0 | 89.88 | 55.29 | 0.005 |
| 16 | 0.5 | 2 | 44.13 | 18.47 | 99.77 | 0 | 50.47 | 0 | 89.87 | 55.92 | 0.001 |
| 16 | 0.5 | 2 | 43.67 | 18.71 | 99.76 | 0 | 50.66 | 0 | 89.88 | 56.2 | 0.001 |
| 16 | 0.5 | 2 | 44.21 | 18.63 | 99.79 | 0 | 50.43 | 0 | 89.87 | 55.88 | 0.001 |
| 16 | 0.5 | 2 | 43.59 | 18.76 | 99.8 | 0 | 50.34 | 0 | 89.87 | 55.87 | 0.001 |
| 16 | 0.5 | 2 | 49.38 | 18.77 | 99.77 | 0 | 50.47 | 0 | 89.87 | 55.93 | 0.005 |
| 16 | 0.5 | 2 | 51.71 | 18.15 | 99.76 | 0 | 50.66 | 0 | 89.88 | 56.2 | 0.005 |
| 16 | 0.5 | 2 | 45.8 | 18.38 | 99.78 | 0 | 50.41 | 0 | 89.87 | 55.88 | 0.005 |
| 16 | 0.5 | 2 | 47.52 | 19.07 | 99.8 | 0 | 50.32 | 0 | 89.87 | 55.86 | 0.005 |
| 64 | 0.5 | 2 | 44.3 | 19.25 | 99.81 | 0 | 51.13 | 0 | 89.87 | 56.22 | 0.001 |
| 64 | 0.5 | 2 | 45.11 | 19.11 | 99.79 | 0 | 51.46 | 0 | 89.88 | 56.48 | 0.001 |
| 64 | 0.5 | 2 | 43.3 | 18.75 | 99.55 | 0 | 51.16 | 0 | 89.88 | 56.33 | 0.001 |
| 64 | 0.5 | 2 | 44.54 | 18.9 | 99.76 | 0 | 51.15 | 0 | 89.88 | 56.42 | 0.001 |
| 64 | 0.5 | 2 | 51.8 | 17.99 | 99.81 | 0 | 51.14 | 0 | 89.87 | 56.23 | 0.005 |
| 64 | 0.5 | 2 | 55.95 | 17.36 | 99.79 | 0 | 51.45 | 0 | 89.88 | 56.47 | 0.005 |
| 64 | 0.5 | 2 | 52.81 | 18.09 | 99.55 | 0 | 51.13 | 0 | 89.88 | 56.33 | 0.005 |
| 64 | 0.5 | 2 | 49.93 | 19.04 | 99.75 | 0 | 51.13 | 0 | 89.88 | 56.42 | 0.005 |
| 8 | 0.5 | 2 | 44.18 | 18.58 | 99.8 | 0 | 48.32 | 0 | 89.88 | 55.18 | 0.001 |
| 8 | 0.5 | 2 | 49.55 | 18.49 | 99.77 | 0 | 48.26 | 0 | 89.88 | 55.18 | 0.001 |
| 8 | 0.5 | 2 | 44.3 | 19.23 | 99.74 | 0 | 48.2 | 0 | 89.88 | 55.12 | 0.001 |
| 8 | 0.5 | 2 | 43.83 | 19.08 | 99.8 | 0 | 48.01 | 0 | 89.88 | 55.29 | 0.001 |
| 8 | 0.5 | 2 | 57.15 | 16.13 | 99.8 | 0 | 48.33 | 0 | 89.88 | 55.17 | 0.005 |
| 8 | 0.5 | 2 | 56.85 | 15.75 | 99.77 | 0 | 48.27 | 0 | 89.88 | 55.18 | 0.005 |
| 8 | 0.5 | 2 | 50.19 | 18.68 | 99.74 | 0 | 48.19 | 0 | 89.88 | 55.12 | 0.005 |
| 8 | 0.5 | 2 | 47.93 | 18.88 | 99.8 | 0 | 47.99 | 0 | 89.88 | 55.28 | 0.005 |
| 16 | 0.5 | 2 | 43.98 | 18.84 | 99.77 | 0 | 50.45 | 0 | 89.87 | 55.91 | 0.001 |
| 16 | 0.5 | 2 | 43.29 | 18.47 | 99.76 | 0 | 50.67 | 0 | 89.88 | 56.22 | 0.001 |
| 16 | 0.5 | 2 | 44.3 | 18.91 | 99.79 | 0 | 50.41 | 0 | 89.87 | 55.88 | 0.001 |
| 16 | 0.5 | 2 | 43.33 | 19.21 | 99.81 | 0 | 50.33 | 0 | 89.87 | 55.87 | 0.001 |
| 16 | 0.5 | 2 | 49.31 | 18.2 | 99.77 | 0 | 50.45 | 0 | 89.87 | 55.92 | 0.005 |
| 16 | 0.5 | 2 | 51.3 | 17.84 | 99.76 | 0 | 50.66 | 0 | 89.88 | 56.2 | 0.005 |
| 16 | 0.5 | 2 | 46.46 | 18.85 | 99.78 | 0 | 50.4 | 0 | 89.87 | 55.88 | 0.005 |
| 16 | 0.5 | 2 | 46.89 | 18.73 | 99.8 | 0 | 50.33 | 0 | 89.87 | 55.87 | 0.005 |
| 64 | 0.5 | 2 | 44.56 | 19.29 | 99.81 | 0 | 51.13 | 0 | 89.87 | 56.24 | 0.001 |
| 64 | 0.5 | 2 | 43.59 | 18.32 | 99.79 | 0 | 51.47 | 0 | 89.88 | 56.48 | 0.001 |
| 64 | 0.5 | 2 | 45.16 | 19.26 | 99.54 | 0 | 51.14 | 0 | 89.88 | 56.33 | 0.001 |
| 64 | 0.5 | 2 | 43.74 | 18.75 | 99.76 | 0 | 51.13 | 0 | 89.88 | 56.42 | 0.001 |
| 64 | 0.5 | 2 | 52.38 | 17.59 | 99.81 | 0 | 51.13 | 0 | 89.87 | 56.23 | 0.005 |
| 64 | 0.5 | 2 | 56.67 | 16.76 | 99.79 | 0 | 51.45 | 0 | 89.88 | 56.48 | 0.005 |
| 64 | 0.5 | 2 | 52.27 | 17.81 | 99.55 | 0 | 51.13 | 0 | 89.88 | 56.33 | 0.005 |
| 64 | 0.5 | 2 | 49.91 | 17.97 | 99.76 | 0 | 51.13 | 0 | 89.88 | 56.43 | 0.005 |
| 8 | 1 | 2 | 45.02 | 18.94 | 99.8 | 0 | 48.22 | 0 | 89.88 | 55.25 | 0.001 |
| 8 | 1 | 2 | 45.19 | 19.48 | 99.8 | 0 | 48.13 | 0 | 89.88 | 55.25 | 0.001 |
| 8 | 1 | 2 | 44.3 | 18.9 | 99.8 | 0 | 48.27 | 0 | 89.88 | 55.29 | 0.001 |
| 8 | 1 | 2 | 44.07 | 18.32 | 99.77 | 0 | 48.09 | 0 | 89.88 | 55.11 | 0.001 |
| 8 | 1 | 2 | 51.23 | 17.85 | 99.81 | 0 | 48.22 | 0 | 89.88 | 55.26 | 0.005 |
| 8 | 1 | 2 | 52.9 | 16.86 | 99.8 | 0 | 48.14 | 0 | 89.88 | 55.25 | 0.005 |
| 8 | 1 | 2 | 58.29 | 16.71 | 99.8 | 0 | 48.29 | 0 | 89.88 | 55.3 | 0.005 |
| 8 | 1 | 2 | 46.67 | 19.49 | 99.77 | 0 | 48.09 | 0 | 89.88 | 55.11 | 0.005 |
| 16 | 1 | 2 | 43.79 | 18.18 | 99.8 | 0 | 50.37 | 0 | 89.88 | 56.09 | 0.001 |
| 16 | 1 | 2 | 44.49 | 18.97 | 99.78 | 0 | 50.57 | 0 | 89.88 | 56.12 | 0.001 |
| 16 | 1 | 2 | 43.37 | 19.1 | 99.81 | 0 | 50.29 | 0 | 89.88 | 55.97 | 0.001 |
| 16 | 1 | 2 | 43.46 | 18.72 | 99.67 | 0 | 50.19 | 0 | 89.88 | 55.82 | 0.001 |
| 16 | 1 | 2 | 49.78 | 18.53 | 99.8 | 0 | 50.36 | 0 | 89.88 | 56.09 | 0.005 |
| 16 | 1 | 2 | 46.8 | 18.2 | 99.78 | 0 | 50.57 | 0 | 89.88 | 56.11 | 0.005 |
| 16 | 1 | 2 | 51.21 | 18.49 | 99.8 | 0 | 50.29 | 0 | 89.88 | 55.97 | 0.005 |
| 16 | 1 | 2 | 49.01 | 19.24 | 99.68 | 0 | 50.21 | 0 | 89.88 | 55.84 | 0.005 |
| 64 | 1 | 2 | 44.97 | 19.28 | 99.78 | 0 | 50.74 | 0 | 89.88 | 56.11 | 0.001 |
| 64 | 1 | 2 | 46.42 | 18.65 | 99.8 | 0 | 50.43 | 0 | 89.87 | 55.83 | 0.001 |
| 64 | 1 | 2 | 45.08 | 19.4 | 99.75 | 0 | 50.9 | 0 | 89.88 | 56.3 | 0.001 |
| 64 | 1 | 2 | 45.16 | 19.32 | 99.8 | 0 | 50.64 | 0 | 89.87 | 56.2 | 0.001 |
| 64 | 1 | 2 | 52.29 | 16.65 | 99.78 | 0 | 50.77 | 0 | 89.88 | 56.14 | 0.005 |
| 64 | 1 | 2 | 51.06 | 17.68 | 99.79 | 0 | 50.44 | 0 | 89.87 | 55.85 | 0.005 |
| 64 | 1 | 2 | 52.01 | 17.52 | 99.75 | 0 | 50.93 | 0 | 89.88 | 56.31 | 0.005 |
| 64 | 1 | 2 | 47.77 | 17.89 | 99.8 | 0 | 50.61 | 0 | 89.87 | 56.19 | 0.005 |
| 8 | 1 | 2 | 44.77 | 19.02 | 99.81 | 0 | 48.23 | 0 | 89.88 | 55.27 | 0.001 |
| 8 | 1 | 2 | 45.83 | 18.74 | 99.8 | 0 | 48.13 | 0 | 89.88 | 55.25 | 0.001 |

Table 3: Complete set of β -VAE Experimentation and Baselines Results with Color Retained.

| Dimensions | Beta | Embedding | ISSM (Color Removed) | PSNR (Color Removed) | RMSE (Color Removed) | SAM (Color Removed) | SRE (Color Removed) | Smoothing |
|------------|------|-----------|----------------------|----------------------|----------------------|---------------------|---------------------|-----------|
| 8 | 0.5 | 2 | 0 | 50.18 | 0 | 89.69 | 54.44 | 0.001 |
| 8 | 0.5 | 2 | 0 | 49.81 | 0 | 89.67 | 54.25 | 0.001 |
| 8 | 0.5 | 2 | 0 | 49.84 | 0 | 89.73 | 54.27 | 0.001 |
| 8 | 0.5 | 2 | 0 | 50.16 | 0 | 89.74 | 54.43 | 0.005 |
| 8 | 0.5 | 2 | 0 | 50.19 | 0 | 89.69 | 54.45 | 0.005 |
| 8 | 0.5 | 2 | 0 | 49.81 | 0 | 89.67 | 54.26 | 0.005 |
| 8 | 0.5 | 2 | 0 | 49.83 | 0 | 89.74 | 54.26 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.65 | 0 | 89.63 | 55.67 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.82 | 0 | 89.72 | 55.76 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.26 | 0 | 89.7 | 55.48 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.54 | 0 | 89.67 | 55.62 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.64 | 0 | 89.63 | 55.67 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.86 | 0 | 89.72 | 55.78 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.22 | 0 | 89.7 | 55.46 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.5 | 0 | 89.67 | 55.6 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.2 | 0 | 89.67 | 55.95 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.55 | 0 | 89.68 | 56.13 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.43 | 0 | 89.66 | 56.07 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.17 | 0 | 89.67 | 55.93 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.2 | 0 | 89.67 | 55.95 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.55 | 0 | 89.68 | 56.12 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.44 | 0 | 89.66 | 56.07 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.14 | 0 | 89.68 | 55.92 | 0.005 |
| 8 | 0.5 | 2 | 0 | 50.16 | 0 | 89.75 | 54.43 | 0.001 |
| 8 | 0.5 | 2 | 0 | 50.18 | 0 | 89.69 | 54.44 | 0.001 |
| 8 | 0.5 | 2 | 0 | 49.83 | 0 | 89.67 | 54.26 | 0.001 |
| 8 | 0.5 | 2 | 0 | 49.85 | 0 | 89.74 | 54.27 | 0.001 |
| 8 | 0.5 | 2 | 0 | 50.16 | 0 | 89.74 | 54.43 | 0.005 |
| 8 | 0.5 | 2 | 0 | 50.18 | 0 | 89.69 | 54.44 | 0.005 |
| 8 | 0.5 | 2 | 0 | 49.82 | 0 | 89.67 | 54.26 | 0.005 |
| 8 | 0.5 | 2 | 0 | 49.83 | 0 | 89.74 | 54.27 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.64 | 0 | 89.63 | 55.67 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.84 | 0 | 89.72 | 55.77 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.23 | 0 | 89.7 | 55.46 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.54 | 0 | 89.67 | 55.62 | 0.001 |
| 16 | 0.5 | 2 | 0 | 52.62 | 0 | 89.63 | 55.66 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.83 | 0 | 89.72 | 55.77 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.22 | 0 | 89.7 | 55.46 | 0.005 |
| 16 | 0.5 | 2 | 0 | 52.52 | 0 | 89.67 | 55.61 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.21 | 0 | 89.67 | 55.96 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.56 | 0 | 89.68 | 56.13 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.44 | 0 | 89.66 | 56.07 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.14 | 0 | 89.67 | 55.92 | 0.001 |
| 64 | 0.5 | 2 | 0 | 53.21 | 0 | 89.67 | 55.95 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.56 | 0 | 89.68 | 56.13 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.44 | 0 | 89.66 | 56.07 | 0.005 |
| 64 | 0.5 | 2 | 0 | 53.15 | 0 | 89.67 | 55.93 | 0.005 |
| 8 | 1 | 2 | 0 | 50.07 | 0 | 89.73 | 54.38 | 0.001 |
| 8 | 1 | 2 | 0 | 49.94 | 0 | 89.75 | 54.32 | 0.001 |
| 8 | 1 | 2 | 0 | 50.12 | 0 | 89.71 | 54.41 | 0.001 |
| 8 | 1 | 2 | 0 | 50.04 | 0 | 89.7 | 54.37 | 0.001 |
| 8 | 1 | 2 | 0 | 50.08 | 0 | 89.74 | 54.39 | 0.005 |
| 8 | 1 | 2 | 0 | 49.95 | 0 | 89.75 | 54.33 | 0.005 |
| 8 | 1 | 2 | 0 | 50.14 | 0 | 89.71 | 54.42 | 0.005 |
| 8 | 1 | 2 | 0 | 50.05 | 0 | 89.7 | 54.37 | 0.005 |
| 16 | 1 | 2 | 0 | 52.2 | 0 | 89.72 | 55.45 | 0.001 |
| 16 | 1 | 2 | 0 | 52.48 | 0 | 89.71 | 55.59 | 0.001 |
| 16 | 1 | 2 | 0 | 52.27 | 0 | 89.7 | 55.49 | 0.001 |
| 16 | 1 | 2 | 0 | 51.87 | 0 | 89.67 | 55.29 | 0.001 |
| 16 | 1 | 2 | 0 | 52.19 | 0 | 89.72 | 55.45 | 0.005 |
| 16 | 1 | 2 | 0 | 52.5 | 0 | 89.71 | 55.6 | 0.005 |
| 16 | 1 | 2 | 0 | 52.27 | 0 | 89.7 | 55.49 | 0.005 |
| 16 | 1 | 2 | 0 | 51.89 | 0 | 89.67 | 55.29 | 0.005 |
| 64 | 1 | 2 | 0 | 52.76 | 0 | 89.68 | 55.73 | 0.001 |
| 64 | 1 | 2 | 0 | 52.47 | 0 | 89.68 | 55.59 | 0.001 |
| 64 | 1 | 2 | 0 | 52.93 | 0 | 89.68 | 55.82 | 0.001 |
| 64 | 1 | 2 | 0 | 52.49 | 0 | 89.69 | 55.6 | 0.001 |
| 64 | 1 | 2 | 0 | 52.78 | 0 | 89.68 | 55.74 | 0.005 |
| 64 | 1 | 2 | 0 | 52.5 | 0 | 89.68 | 55.6 | 0.005 |
| 64 | 1 | 2 | 0 | 52.95 | 0 | 89.68 | 55.83 | 0.005 |
| 64 | 1 | 2 | 0 | 52.46 | 0 | 89.69 | 55.58 | 0.005 |
| 8 | 1 | 2 | 0 | 50.09 | 0 | 89.74 | 54.4 | 0.001 |
| 8 | 1 | 2 | 0 | 49.94 | 0 | 89.74 | 54.32 | 0.001 |
| 8 | 1 | 2 | 0 | 50.13 | 0 | 89.71 | 54.41 | 0.001 |
| 8 | 1 | 2 | 0 | 50.04 | 0 | 89.7 | 54.37 | 0.001 |
| 8 | 1 | 2 | 0 | 50.08 | 0 | 89.74 | 54.39 | 0.005 |
| 8 | 1 | 2 | 0 | 49.95 | 0 | 89.75 | 54.32 | 0.005 |
| 8 | 1 | 2 | 0 | 50.11 | 0 | 89.71 | 54.41 | 0.005 |
| 8 | 1 | 2 | 0 | 50.04 | 0 | 89.71 | 54.37 | 0.005 |
| 16 | 1 | 2 | 0 | 52.2 | 0 | 89.71 | 55.45 | 0.001 |
| 16 | 1 | 2 | 0 | 52.49 | 0 | 89.7 | 55.6 | 0.001 |
| 16 | 1 | 2 | 0 | 52.25 | 0 | 89.7 | 55.47 | 0.001 |
| 16 | 1 | 2 | 0 | 51.88 | 0 | 89.67 | 55.29 | 0.001 |
| 16 | 1 | 2 | 0 | 52.2 | 0 | 89.71 | 55.45 | 0.005 |
| 16 | 1 | 2 | 0 | 52.53 | 0 | 89.71 | 55.62 | 0.005 |
| 16 | 1 | 2 | 0 | 52.27 | 0 | 89.7 | 55.48 | 0.005 |
| 16 | 1 | 2 | 0 | 51.9 | 0 | 89.67 | 55.3 | 0.005 |
| 64 | 1 | 2 | 0 | 52.77 | 0 | 89.68 | 55.74 | 0.001 |
| 64 | 1 | 2 | 0 | 52.52 | 0 | 89.68 | 55.61 | 0.001 |
| 64 | 1 | 2 | 0 | 52.92 | 0 | 89.68 | 55.81 | 0.001 |
| 64 | 1 | 2 | 0 | 52.46 | 0 | 89.7 | 55.58 | 0.001 |
| 64 | 1 | 2 | 0 | 52.8 | 0 | 89.68 | 55.75 | 0.005 |
| 64 | 1 | 2 | 0 | 52.51 | 0 | 89.68 | 55.61 | 0.005 |
| 64 | 1 | 2 | 0 | 52.92 | 0 | 89.68 | 55.81 | 0.005 |
| 64 | 1 | 2 | 0 | 52.47 | 0 | 89.69 | 55.59 | 0.005 |
| 8 | 2.5 | 2 | 0 | 49.71 | 0 | 89.72 | 54.2 | 0.001 |
| 8 | 2.5 | 2 | 0 | 49.73 | 0 | 89.74 | 54.22 | 0.001 |
| 8 | 2.5 | 2 | 0 | 49.53 | 0 | 89.73 | 54.11 | 0.001 |
| 8 | 2.5 | 2 | 0 | 49.9 | 0 | 89.72 | 54.3 | 0.001 |
| 8 | 2.5 | 2 | 0 | 49.68 | 0 | 89.72 | 54.19 | 0.005 |
| 8 | 2.5 | 2 | 0 | 49.75 | 0 | 89.74 | 54.22 | 0.005 |
| 8 | 2.5 | 2 | 0 | 49.55 | 0 | 89.73 | 54.12 | 0.005 |
| 8 | 2.5 | 2 | 0 | 49.87 | 0 | 89.71 | 54.29 | 0.005 |

Table 4: Complete set of β -VAE Experimentation and Baselines Results with Color Removed.