

Supplementary Document for Hedged Deep Tracking

Anonymous CVPR submission

Paper ID 1497

In this supplementary material, we present additional evaluation on the proposed HDT algorithm and the state-of-the-art methods on both the benchmark dataset with 100 sequences (*benchmark-100*) [9] and the benchmark dataset with 50 sequences (*benchmark-50*) [8]. We first summarize the evaluated trackers in Section 1, and then present distance precision rate and overlap success rate on each sequence of the benchmark-100 dataset in Section 2. The robustness evaluation on the benchmark-50 dataset is presented in Section 3. Additional attribute based evaluation on both the benchmark-100 and the benchmark-50 datasets is presented in Section 4.

1. Evaluated trackers

The evaluated trackers are categorized into four groups:

- two recent deep learning trackers: DLT [7] and CNN-SVM [5];
- one excellent correlation filtered tracker KCF [4];
- five state-of-the-art trackers based on tracking benchmark [8]: MEEM [10], Struck [3], CXT [2], TLD [6], and SCM [11];
- four baselines: HDT-SH, VGG-12, VGG-15, and VGG-16. HDT-SH hedges all weak trackers using the standard parameter-free hedging algorithm [1], and the remaining are three best-performed weak trackers on the 12th, 15th, 16th convolutional layers, respectively.

We use the source codes from the authors except CNN-SVM, which only provides the one-pass evaluation results on the benchmark-50 dataset. Therefore, we use symbol ‘–’ to denote the unavailable results of CNN-SVM.

2. Distance Precision Rate and Overlap Success Rate

In this section, we present distance precision rate (Subsection 2.1) and overlap success rate (Subsection 2.2) on each sequence of the benchmark-100 dataset.

2.1. Distance precision rate

The distance precision rate is calculated at a threshold of 20 pixels. Tables 1 and 2 show the distance precision rates calculated from the first and second halves of the benchmark-100 dataset, respectively. The results demonstrate that the proposed HDT algorithm performs favorably against the other trackers on most sequences and achieves the best average performance.

2.2. Overlap success rate

Tables 3 and 4 report the overlap rates at a threshold of 0.5 computed from the first and second halves of the benchmark-100 dataset, respectively. Overall, the proposed HDT algorithm performs well against all the evaluated methods.

3. Robustness Evaluation

In the manuscript, we report robustness evaluation tested on the benchmark-100 dataset. In this section, we report robustness evaluation on the benchmark-50 dataset. As shown in Figure 1, the proposed HDT algorithm performs favorably against the state-of-the-art trackers.

Table 1. Distance precision rates computed from the first half of the benchmark-100 dataset [9].

| | HDT | DLT | CNN-SVM | KCF | MEEM | Struck | CXT | TLD | SCM | HDT-SH | VGG-16 | VGG-15 | VGG-12 |
|--------------|-------|-------|---------|-------|-------|--------|-------|-------|-------|--------|--------|--------|--------|
| basketball | 1.000 | 0.086 | 0.341 | 0.923 | 0.892 | 0.120 | 0.037 | 0.028 | 0.661 | 1.000 | 1.000 | 1.000 | 1.000 |
| bolt | 1.000 | 0.026 | 1.000 | 0.989 | 0.966 | 0.020 | 0.026 | 0.306 | 0.031 | 1.000 | 1.000 | 1.000 | 1.000 |
| boy | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.937 | 1.000 | 0.440 | 1.000 | 1.000 | 1.000 | 1.000 |
| car4 | 0.991 | 1.000 | 1.000 | 0.953 | 0.686 | 0.992 | 0.382 | 0.874 | 0.974 | 0.995 | 0.977 | 0.985 | 1.000 |
| carDark | 1.000 | 0.715 | 1.000 | 1.000 | 1.000 | 1.000 | 0.728 | 0.639 | 1.000 | 0.997 | 1.000 | 1.000 | 1.000 |
| carScale | 0.619 | 0.714 | 0.702 | 0.806 | 0.651 | 0.647 | 0.742 | 0.853 | 0.647 | 0.718 | 0.563 | 0.627 | 0.706 |
| coke | 0.966 | 0.340 | 0.928 | 0.838 | 0.945 | 0.948 | 0.653 | 0.684 | 0.430 | 0.935 | 0.928 | 0.931 | 0.859 |
| couple | 0.893 | 0.307 | 1.000 | 0.257 | 1.000 | 0.736 | 0.636 | 1.000 | 0.114 | 0.714 | 0.929 | 0.671 | 0.693 |
| crossing | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.625 | 0.617 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| david | 1.000 | 0.321 | 1.000 | 1.000 | 0.904 | 0.329 | 1.000 | 1.000 | 1.000 | 1.000 | 0.970 | 1.000 | 1.000 |
| david2 | 1.000 | 0.711 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.911 | 1.000 | 1.000 | 1.000 |
| david3 | 1.000 | 0.698 | 0.996 | 1.000 | 0.996 | 0.337 | 0.151 | 0.111 | 0.496 | 1.000 | 1.000 | 1.000 | 1.000 |
| deer | 1.000 | 0.042 | 1.000 | 0.817 | 1.000 | 1.000 | 1.000 | 0.732 | 0.028 | 1.000 | 0.986 | 0.972 | 1.000 |
| dog1 | 0.994 | 0.996 | 0.919 | 1.000 | 0.982 | 0.996 | 1.000 | 1.000 | 0.976 | 0.990 | 0.996 | 0.979 | 0.979 |
| doll | 0.980 | 0.957 | 0.950 | 0.968 | 0.985 | 0.919 | 0.986 | 0.983 | 0.978 | 0.988 | 0.980 | 0.982 | 0.982 |
| dudek | 0.886 | 0.918 | 0.905 | 0.877 | 0.792 | 0.897 | 0.822 | 0.597 | 0.883 | 0.854 | 0.893 | 0.918 | 0.859 |
| faceocc1 | 0.676 | 0.462 | 0.306 | 0.730 | 0.683 | 0.575 | 0.342 | 0.203 | 0.933 | 0.632 | 0.422 | 0.433 | 0.831 |
| faceocc2 | 0.968 | 0.850 | 0.999 | 0.972 | 0.986 | 1.000 | 1.000 | 0.856 | 0.860 | 0.982 | 0.999 | 0.998 | 0.920 |
| fish | 1.000 | 0.401 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.863 | 1.000 | 1.000 | 1.000 | 1.000 |
| fleetface | 0.553 | 0.434 | 0.668 | 0.460 | 0.591 | 0.639 | 0.573 | 0.506 | 0.529 | 0.560 | 0.620 | 0.560 | 0.537 |
| football | 1.000 | 0.296 | 0.964 | 0.796 | 0.992 | 0.751 | 0.796 | 0.804 | 0.765 | 1.000 | 1.000 | 1.000 | 1.000 |
| football1 | 0.986 | 0.608 | 0.865 | 0.959 | 1.000 | 1.000 | 1.000 | 0.554 | 0.568 | 0.959 | 0.973 | 0.568 | 0.973 |
| freeman1 | 0.982 | 0.380 | 0.985 | 0.402 | 0.997 | 0.801 | 0.730 | 0.540 | 0.982 | 0.936 | 0.979 | 0.377 | 0.411 |
| freeman3 | 0.909 | 1.000 | 0.985 | 0.911 | 0.985 | 0.789 | 1.000 | 0.767 | 1.000 | 0.863 | 0.835 | 0.839 | 0.815 |
| freeman4 | 0.852 | 0.346 | 0.852 | 0.534 | 0.565 | 0.375 | 0.431 | 0.410 | 0.509 | 0.173 | 0.943 | 0.360 | 0.484 |
| girl | 1.000 | 0.776 | 1.000 | 0.864 | 1.000 | 1.000 | 0.768 | 0.918 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| ironman | 0.669 | 0.127 | 0.072 | 0.217 | 0.506 | 0.114 | 0.042 | 0.120 | 0.157 | 0.645 | 0.410 | 0.590 | 0.657 |
| jogging-1 | 0.974 | 0.228 | 0.984 | 0.235 | 0.964 | 0.241 | 0.961 | 0.974 | 0.228 | 0.974 | 0.974 | 0.974 | 0.228 |
| jogging-2 | 1.000 | 0.173 | 1.000 | 0.163 | 0.971 | 0.254 | 0.163 | 0.857 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| jumping | 1.000 | 0.962 | 1.000 | 0.342 | 1.000 | 1.000 | 0.997 | 1.000 | 0.153 | 1.000 | 1.000 | 0.990 | 0.994 |
| lemming | 0.274 | 0.298 | 0.689 | 0.487 | 0.911 | 0.628 | 0.728 | 0.859 | 0.166 | 0.019 | 0.424 | 0.263 | 0.274 |
| liquor | 0.717 | 0.357 | 0.933 | 0.976 | 0.925 | 0.390 | 0.209 | 0.588 | 0.276 | 0.817 | 0.718 | 0.718 | 0.991 |
| matrix | 0.580 | 0.010 | 0.130 | 0.170 | 0.640 | 0.120 | 0.060 | 0.160 | 0.350 | 0.640 | 0.560 | 0.290 | 0.650 |
| mhyang | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| motorRolling | 0.817 | 0.043 | 0.884 | 0.049 | 0.061 | 0.085 | 0.037 | 0.116 | 0.037 | 0.104 | 0.957 | 0.884 | 0.793 |
| mountainBike | 1.000 | 0.811 | 1.000 | 1.000 | 0.917 | 0.921 | 0.281 | 0.259 | 0.969 | 1.000 | 0.991 | 1.000 | 1.000 |
| shaking | 0.819 | 0.926 | 0.973 | 0.019 | 0.995 | 0.192 | 0.126 | 0.405 | 0.814 | 0.959 | 0.953 | 0.849 | 0.027 |
| singer1 | 1.000 | 1.000 | 0.954 | 0.843 | 0.470 | 0.641 | 0.966 | 1.000 | 1.000 | 1.000 | 0.954 | 1.000 | 0.983 |
| singer2 | 0.036 | 0.036 | 0.828 | 0.948 | 0.038 | 0.036 | 0.063 | 0.071 | 0.112 | 0.036 | 0.041 | 0.041 | 0.033 |
| skating1 | 1.000 | 0.763 | 0.440 | 1.000 | 0.693 | 0.465 | 0.235 | 0.318 | 0.768 | 1.000 | 1.000 | 1.000 | 1.000 |
| skiing | 1.000 | 0.123 | 1.000 | 0.074 | 1.000 | 0.037 | 0.148 | 0.123 | 0.136 | 0.136 | 0.395 | 1.000 | 0.123 |
| soccer | 0.878 | 0.138 | 0.242 | 0.791 | 0.314 | 0.253 | 0.232 | 0.115 | 0.268 | 0.875 | 0.625 | 0.546 | 0.890 |
| subway | 1.000 | 0.023 | 1.000 | 1.000 | 1.000 | 0.983 | 0.257 | 0.251 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| suv | 0.950 | 1.000 | 0.940 | 0.979 | 0.743 | 0.572 | 0.914 | 0.909 | 0.978 | 0.979 | 0.843 | 0.978 | 0.980 |
| sylvester | 0.996 | 0.770 | 0.996 | 0.843 | 0.954 | 0.995 | 0.852 | 0.949 | 0.946 | 0.995 | 0.857 | 0.994 | 0.854 |
| tiger1 | 0.931 | 0.433 | 0.559 | 0.851 | 0.822 | 0.175 | 0.372 | 0.456 | 0.126 | 0.934 | 0.702 | 0.722 | 0.934 |
| tiger2 | 0.575 | 0.329 | 0.584 | 0.356 | 0.488 | 0.630 | 0.342 | 0.386 | 0.112 | 0.586 | 0.499 | 0.603 | 0.630 |
| trellis | 1.000 | 0.339 | 1.000 | 1.000 | 0.968 | 0.877 | 0.970 | 0.529 | 0.873 | 1.000 | 0.989 | 0.998 | 1.000 |
| walking | 1.000 | 0.748 | 1.000 | 1.000 | 1.000 | 1.000 | 0.235 | 0.964 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| walking2 | 0.904 | 1.000 | 0.862 | 0.434 | 0.392 | 0.982 | 0.406 | 0.426 | 1.000 | 0.402 | 0.400 | 0.404 | 1.000 |
| woman | 0.940 | 0.938 | 0.998 | 0.938 | 0.963 | 1.000 | 0.367 | 0.191 | 0.940 | 0.940 | 0.940 | 0.963 | 0.940 |

Table 2. Distance precision rates computed from the second half of the benchmark-100 dataset [9]. The average scores are computed over the whole benchmark.

| | HDT | DLT | CNN-SVM | KCF | MEEM | Struck | CXT | TLD | SCM | HDT-SH | VGG-16 | VGG-15 | VGG-12 |
|------------|-------|-------|---------|-------|-------|--------|-------|-------|-------|--------|--------|--------|--------|
| biker | 0.514 | 0.958 | — | 0.507 | 0.535 | 0.556 | 0.535 | 0.514 | 0.500 | 0.500 | 0.514 | 0.493 | 0.500 |
| bird1 | 0.600 | 0.588 | — | 0.069 | 0.289 | 0.150 | 0.027 | 0.010 | 0.517 | 0.338 | 0.608 | 0.620 | 0.350 |
| bird2 | 0.970 | 0.202 | — | 0.475 | 1.000 | 0.545 | 0.192 | 0.859 | 0.899 | 0.949 | 0.990 | 1.000 | 0.970 |
| blurBody | 0.985 | 0.045 | — | 0.584 | 0.886 | 0.814 | 0.949 | 0.449 | 0.093 | 0.964 | 0.940 | 0.931 | 0.994 |
| blurCar1 | 0.977 | 0.026 | — | 0.995 | 0.993 | 0.996 | 0.344 | 0.821 | 0.022 | 0.996 | 0.988 | 0.992 | 0.997 |
| blurCar2 | 0.957 | 0.749 | — | 0.938 | 0.959 | 0.916 | 0.974 | 0.979 | 0.099 | 0.973 | 0.918 | 0.915 | 1.000 |
| blurCar3 | 0.997 | 0.252 | — | 0.994 | 1.000 | 1.000 | 1.000 | 0.952 | 0.157 | 1.000 | 0.997 | 1.000 | 1.000 |
| blurCar4 | 0.995 | 0.563 | — | 0.997 | 0.976 | 0.997 | 0.997 | 0.803 | 0.179 | 1.000 | 0.987 | 0.976 | 1.000 |
| blurFace | 0.994 | 0.191 | — | 1.000 | 0.990 | 0.436 | 1.000 | 1.000 | 0.112 | 1.000 | 0.982 | 0.982 | 1.000 |
| blurOwl | 0.962 | 0.070 | — | 0.228 | 0.995 | 0.989 | 0.978 | 0.713 | 0.190 | 0.964 | 0.903 | 0.924 | 0.594 |
| board | 0.910 | 0.570 | — | 0.656 | 0.605 | 0.752 | 0.113 | 0.011 | 0.441 | 0.911 | 0.666 | 0.778 | 0.915 |
| bolt2 | 0.990 | 0.973 | — | 0.017 | 0.017 | 0.109 | 0.017 | 0.014 | 0.014 | 0.949 | 0.908 | 0.017 | 0.017 |
| box | 0.051 | 0.396 | — | 0.415 | 0.370 | 0.239 | 0.339 | 0.742 | 0.153 | 0.051 | 0.171 | 0.333 | 0.411 |
| car1 | 0.714 | 1.000 | — | 0.739 | 0.196 | 0.334 | 0.601 | 0.417 | 1.000 | 0.449 | 0.391 | 0.697 | 0.741 |
| car2 | 1.000 | 1.000 | — | 1.000 | 1.000 | 1.000 | 0.964 | 1.000 | 1.000 | 0.851 | 0.989 | 1.000 | 1.000 |
| car24 | 1.000 | 1.000 | — | 1.000 | 1.000 | 0.170 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 1.000 |
| clifBar | 0.831 | 0.464 | — | 0.445 | 0.941 | 0.261 | 0.301 | 0.298 | 0.173 | 0.375 | 0.771 | 0.180 | 0.911 |
| coupon | 1.000 | 0.382 | — | 1.000 | 0.394 | 1.000 | 1.000 | 0.740 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| crowds | 1.000 | 0.916 | — | 1.000 | 1.000 | 0.911 | 0.127 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| dancer | 1.000 | 0.964 | — | 1.000 | 0.916 | 0.987 | 0.680 | 0.951 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| dancer2 | 1.000 | 1.000 | — | 1.000 | 0.980 | 1.000 | 1.000 | 0.853 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| diving | 0.753 | 0.256 | — | 0.535 | 0.209 | 0.521 | 0.191 | 0.158 | 0.540 | 0.758 | 0.740 | 0.637 | 0.563 |
| dog | 0.984 | 0.961 | — | 0.992 | 1.000 | 0.945 | 1.000 | 1.000 | 0.953 | 1.000 | 0.976 | 1.000 | 1.000 |
| dragonBaby | 0.876 | 0.372 | — | 0.336 | 0.823 | 0.106 | 0.575 | 0.257 | 0.283 | 0.823 | 0.850 | 0.814 | 0.779 |
| girl2 | 0.073 | 0.074 | — | 0.071 | 0.801 | 0.272 | 0.177 | 0.077 | 0.343 | 0.073 | 0.073 | 0.106 | 0.073 |
| gym | 0.984 | 0.146 | — | 0.795 | 0.913 | 0.597 | 0.755 | 0.641 | 0.342 | 0.967 | 0.980 | 0.910 | 0.978 |
| human2 | 0.587 | 0.556 | — | 0.171 | 0.180 | 0.432 | 0.280 | 0.257 | 0.354 | 0.514 | 0.510 | 0.438 | 0.602 |
| human3 | 0.376 | 0.009 | — | 0.006 | 0.866 | 0.010 | 0.011 | 0.008 | 0.009 | 0.034 | 0.037 | 0.032 | 0.035 |
| human4 | 0.859 | 0.205 | — | 0.534 | 0.504 | 0.211 | 0.109 | 0.118 | 0.192 | 0.958 | 0.516 | 0.510 | 0.928 |
| human5 | 0.987 | 0.891 | — | 0.265 | 0.997 | 0.990 | 0.328 | 1.000 | 0.933 | 0.244 | 0.244 | 0.244 | 0.245 |
| human6 | 0.439 | 0.446 | — | 0.290 | 0.663 | 0.255 | 0.172 | 0.458 | 0.322 | 0.477 | 0.284 | 0.303 | 0.294 |
| human7 | 1.000 | 0.436 | — | 0.472 | 1.000 | 1.000 | 0.964 | 1.000 | 0.368 | 1.000 | 1.000 | 1.000 | 1.000 |
| human8 | 1.000 | 0.219 | — | 1.000 | 1.000 | 0.195 | 0.188 | 0.188 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| human9 | 1.000 | 0.321 | — | 0.725 | 0.498 | 0.282 | 0.118 | 0.213 | 0.203 | 1.000 | 1.000 | 1.000 | 1.000 |
| jump | 0.107 | 0.066 | — | 0.057 | 0.066 | 0.082 | 0.066 | 0.066 | 0.074 | 0.057 | 0.033 | 0.115 | 0.090 |
| kiteSurf | 0.464 | 0.286 | — | 0.333 | 1.000 | 0.905 | 0.417 | 0.464 | 0.333 | 0.464 | 1.000 | 1.000 | 1.000 |
| man | 1.000 | 1.000 | — | 1.000 | 1.000 | 1.000 | 0.985 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| panda | 0.992 | 0.996 | — | 0.364 | 1.000 | 1.000 | 0.314 | 0.729 | 0.993 | 0.998 | 0.991 | 0.893 | 0.410 |
| redTeam | 1.000 | 1.000 | — | 1.000 | 1.000 | 1.000 | 0.650 | 0.721 | 1.000 | 1.000 | 1.000 | 0.986 | 1.000 |
| rubik | 0.655 | 0.359 | — | 0.969 | 0.536 | 0.307 | 0.231 | 0.989 | 0.216 | 0.934 | 0.819 | 0.838 | 0.985 |
| skater | 0.994 | 0.981 | — | 0.938 | 0.925 | 0.994 | 0.994 | 0.925 | 0.781 | 0.981 | 0.994 | 0.994 | 0.994 |
| skater2 | 0.878 | 0.237 | — | 0.694 | 0.913 | 0.726 | 0.345 | 0.379 | 0.694 | 0.637 | 0.880 | 0.926 | 0.547 |
| skating2-1 | 0.632 | 0.040 | — | 0.383 | 0.273 | 0.190 | 0.161 | 0.034 | 0.061 | 0.469 | 0.588 | 0.469 | 0.643 |
| skating2-2 | 0.406 | 0.114 | — | 0.490 | 0.178 | 0.292 | 0.040 | 0.025 | 0.283 | 0.171 | 0.558 | 0.351 | 0.378 |
| surfer | 1.000 | 0.585 | — | 0.910 | 0.987 | 0.971 | 1.000 | 1.000 | 0.707 | 1.000 | 0.995 | 1.000 | 1.000 |
| toy | 0.867 | 0.214 | — | 0.985 | 0.745 | 0.897 | 0.996 | 0.934 | 0.258 | 0.624 | 0.875 | 0.804 | 0.679 |
| trans | 0.339 | 0.185 | — | 0.306 | 0.210 | 0.226 | 0.387 | 0.419 | 0.250 | 0.331 | 0.290 | 0.331 | 0.347 |
| twinnings | 1.000 | 0.998 | — | 0.907 | 0.987 | 1.000 | 0.559 | 0.623 | 0.725 | 0.411 | 1.000 | 0.413 | 1.000 |
| vase | 0.756 | 0.413 | — | 0.793 | 0.476 | 0.513 | 0.683 | 0.531 | 0.376 | 0.572 | 0.808 | 0.583 | 0.531 |
| Average | 0.848 | 0.526 | 0.434 | 0.692 | 0.781 | 0.635 | 0.552 | 0.593 | 0.572 | 0.780 | 0.810 | 0.775 | 0.785 |

Table 3. Overlap success rates computed from the first half of the benchmark-100 dataset [9].

| | HDT | DLT | CNN-SVM | KCF | MEEM | Struck | CXT | TLD | SCM | HDT-SH | VGG-16 | VGG-15 | VGG-12 |
|--------------|-------|-------|---------|-------|-------|--------|-------|-------|-------|--------|--------|--------|--------|
| basketball | 1.000 | 0.057 | 0.494 | 0.901 | 0.861 | 0.102 | 0.025 | 0.025 | 0.611 | 0.989 | 0.994 | 0.983 | 0.996 |
| bolt | 0.991 | 0.017 | 1.000 | 0.934 | 0.283 | 0.017 | 0.017 | 0.146 | 0.014 | 0.937 | 0.903 | 0.983 | 0.997 |
| boy | 0.992 | 1.000 | 0.987 | 0.992 | 0.990 | 0.977 | 0.497 | 0.935 | 0.439 | 0.992 | 0.968 | 0.983 | 0.992 |
| car4 | 0.396 | 1.000 | 0.408 | 0.367 | 0.349 | 0.398 | 0.299 | 0.792 | 0.973 | 0.399 | 0.376 | 0.396 | 0.399 |
| carDark | 0.865 | 0.682 | 0.972 | 0.723 | 1.000 | 1.000 | 0.690 | 0.529 | 0.997 | 0.789 | 0.842 | 0.807 | 0.977 |
| carScale | 0.401 | 0.706 | 0.433 | 0.444 | 0.373 | 0.433 | 0.782 | 0.437 | 0.651 | 0.448 | 0.417 | 0.337 | 0.444 |
| coke | 0.921 | 0.326 | 0.735 | 0.729 | 0.921 | 0.942 | 0.591 | 0.292 | 0.337 | 0.698 | 0.921 | 0.876 | 0.753 |
| couple | 0.693 | 0.286 | 0.814 | 0.243 | 0.757 | 0.543 | 0.564 | 1.000 | 0.107 | 0.686 | 0.750 | 0.621 | 0.650 |
| crossing | 0.967 | 0.992 | 0.917 | 0.933 | 0.958 | 0.942 | 0.342 | 0.517 | 1.000 | 0.950 | 0.842 | 0.967 | 0.967 |
| david | 0.624 | 0.270 | 0.656 | 0.622 | 0.597 | 0.236 | 0.839 | 0.970 | 0.915 | 0.620 | 0.539 | 0.620 | 0.624 |
| david2 | 1.000 | 0.475 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.952 | 0.911 | 0.760 | 0.860 | 0.937 | 1.000 |
| david3 | 1.000 | 0.504 | 0.992 | 0.992 | 0.933 | 0.337 | 0.139 | 0.103 | 0.484 | 1.000 | 0.992 | 1.000 | 1.000 |
| deer | 1.000 | 0.042 | 1.000 | 0.817 | 1.000 | 1.000 | 0.930 | 0.732 | 0.028 | 1.000 | 0.986 | 0.972 | 1.000 |
| dog1 | 0.653 | 0.884 | 0.616 | 0.653 | 0.653 | 0.653 | 0.998 | 0.673 | 0.847 | 0.645 | 0.627 | 0.627 | 0.649 |
| doll | 0.730 | 0.960 | 0.669 | 0.552 | 0.730 | 0.688 | 0.976 | 0.626 | 0.987 | 0.730 | 0.730 | 0.726 | 0.729 |
| dudek | 0.976 | 0.978 | 0.977 | 0.976 | 0.978 | 0.980 | 0.924 | 0.842 | 0.976 | 0.972 | 0.966 | 0.975 | 0.975 |
| faceocc1 | 1.000 | 0.591 | 0.979 | 1.000 | 1.000 | 1.000 | 0.771 | 0.834 | 1.000 | 0.998 | 0.776 | 0.976 | 1.000 |
| faceocc2 | 0.996 | 0.736 | 0.999 | 0.996 | 0.996 | 1.000 | 0.946 | 0.829 | 0.874 | 0.998 | 1.000 | 1.000 | 0.973 |
| fish | 1.000 | 0.372 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.964 | 0.863 | 1.000 | 1.000 | 1.000 | 1.000 |
| fleetface | 0.593 | 0.421 | 0.844 | 0.669 | 0.777 | 0.666 | 0.646 | 0.571 | 0.706 | 0.580 | 0.720 | 0.622 | 0.591 |
| football | 0.950 | 0.293 | 0.948 | 0.682 | 0.959 | 0.660 | 0.657 | 0.412 | 0.586 | 0.934 | 0.994 | 0.989 | 0.917 |
| football1 | 0.959 | 0.324 | 0.865 | 0.959 | 0.838 | 0.878 | 0.973 | 0.392 | 0.405 | 0.905 | 0.905 | 0.568 | 0.973 |
| freeman1 | 0.258 | 0.334 | 0.294 | 0.160 | 0.212 | 0.218 | 0.258 | 0.212 | 0.807 | 0.270 | 0.273 | 0.178 | 0.175 |
| freeman3 | 0.307 | 0.852 | 0.257 | 0.278 | 0.309 | 0.200 | 0.937 | 0.583 | 0.930 | 0.309 | 0.274 | 0.293 | 0.307 |
| freeman4 | 0.445 | 0.155 | 0.283 | 0.194 | 0.329 | 0.159 | 0.180 | 0.269 | 0.247 | 0.152 | 0.413 | 0.223 | 0.223 |
| girl | 0.974 | 0.670 | 0.982 | 0.756 | 0.948 | 0.980 | 0.642 | 0.764 | 0.884 | 0.974 | 0.938 | 0.974 | 0.972 |
| ironman | 0.620 | 0.060 | 0.072 | 0.157 | 0.434 | 0.048 | 0.030 | 0.066 | 0.133 | 0.590 | 0.349 | 0.536 | 0.608 |
| jogging-1 | 0.967 | 0.221 | 0.971 | 0.225 | 0.909 | 0.225 | 0.954 | 0.967 | 0.212 | 0.967 | 0.964 | 0.967 | 0.225 |
| jogging-2 | 1.000 | 0.156 | 0.990 | 0.160 | 0.909 | 0.248 | 0.153 | 0.831 | 0.990 | 1.000 | 0.984 | 1.000 | 1.000 |
| jumping | 0.994 | 0.700 | 0.917 | 0.281 | 0.987 | 0.799 | 0.288 | 0.847 | 0.121 | 1.000 | 0.984 | 0.974 | 0.994 |
| lemming | 0.269 | 0.243 | 0.712 | 0.432 | 0.853 | 0.641 | 0.610 | 0.594 | 0.166 | 0.028 | 0.442 | 0.264 | 0.266 |
| liquor | 0.717 | 0.363 | 0.976 | 0.982 | 0.978 | 0.406 | 0.210 | 0.582 | 0.321 | 0.814 | 0.719 | 0.720 | 0.987 |
| matrix | 0.370 | 0.010 | 0.070 | 0.130 | 0.380 | 0.120 | 0.040 | 0.070 | 0.300 | 0.470 | 0.290 | 0.230 | 0.430 |
| mhyang | 1.000 | 1.000 | 0.998 | 1.000 | 0.997 | 1.000 | 1.000 | 0.893 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 |
| motorRolling | 0.524 | 0.073 | 0.567 | 0.079 | 0.110 | 0.159 | 0.018 | 0.171 | 0.073 | 0.122 | 0.604 | 0.579 | 0.488 |
| mountainBike | 0.991 | 0.320 | 1.000 | 0.991 | 0.838 | 0.855 | 0.281 | 0.259 | 0.961 | 0.996 | 0.991 | 0.991 | 0.996 |
| shaking | 0.805 | 0.929 | 0.904 | 0.014 | 0.956 | 0.167 | 0.107 | 0.400 | 0.896 | 0.932 | 0.899 | 0.838 | 0.016 |
| singer1 | 0.276 | 1.000 | 0.296 | 0.276 | 0.271 | 0.299 | 0.322 | 0.991 | 1.000 | 0.276 | 0.276 | 0.276 | 0.276 |
| singer2 | 0.036 | 0.036 | 0.954 | 0.970 | 0.038 | 0.036 | 0.038 | 0.101 | 0.164 | 0.036 | 0.041 | 0.041 | 0.033 |
| skating1 | 0.383 | 0.485 | 0.333 | 0.363 | 0.385 | 0.370 | 0.120 | 0.228 | 0.423 | 0.373 | 0.413 | 0.375 | 0.355 |
| skiing | 0.296 | 0.111 | 0.370 | 0.062 | 0.321 | 0.037 | 0.086 | 0.074 | 0.086 | 0.111 | 0.173 | 0.383 | 0.099 |
| soccer | 0.459 | 0.138 | 0.230 | 0.390 | 0.301 | 0.156 | 0.128 | 0.122 | 0.237 | 0.385 | 0.314 | 0.423 | 0.393 |
| subway | 1.000 | 0.017 | 0.971 | 0.994 | 0.966 | 0.909 | 0.229 | 0.229 | 0.994 | 0.989 | 1.000 | 1.000 | 1.000 |
| suv | 0.953 | 1.000 | 0.942 | 0.985 | 0.749 | 0.575 | 0.915 | 0.839 | 0.984 | 0.984 | 0.838 | 0.972 | 0.984 |
| sylvester | 0.975 | 0.512 | 0.987 | 0.819 | 0.913 | 0.929 | 0.748 | 0.928 | 0.888 | 0.961 | 0.826 | 0.975 | 0.850 |
| tiger1 | 0.948 | 0.298 | 0.708 | 0.857 | 0.917 | 0.183 | 0.278 | 0.456 | 0.129 | 0.946 | 0.722 | 0.754 | 0.946 |
| tiger2 | 0.573 | 0.181 | 0.660 | 0.364 | 0.496 | 0.652 | 0.288 | 0.175 | 0.112 | 0.581 | 0.501 | 0.597 | 0.627 |
| trellis | 0.840 | 0.318 | 0.851 | 0.840 | 0.819 | 0.784 | 0.810 | 0.473 | 0.854 | 0.842 | 0.821 | 0.819 | 0.842 |
| walking | 0.551 | 0.471 | 0.495 | 0.515 | 0.517 | 0.566 | 0.218 | 0.383 | 0.959 | 0.522 | 0.478 | 0.544 | 0.546 |
| walking2 | 0.398 | 1.000 | 0.430 | 0.378 | 0.352 | 0.434 | 0.398 | 0.340 | 1.000 | 0.382 | 0.384 | 0.380 | 0.406 |
| woman | 0.935 | 0.802 | 0.935 | 0.936 | 0.333 | 0.935 | 0.206 | 0.166 | 0.858 | 0.923 | 0.931 | 0.849 | 0.925 |

Table 4. Overlap success rates computed from the second half of the benchmark-100 dataset [9]. The average scores are computed over the whole benchmark.

| | HDT | DLT | CNN-SVM | KCF | MEEM | Struck | CXT | TLD | SCM | HDT-SH | VGG-16 | VGG-15 | VGG-12 |
|------------|-------|-------|---------|-------|-------|--------|-------|-------|-------|--------|--------|--------|--------|
| biker | 0.225 | 0.500 | — | 0.254 | 0.254 | 0.254 | 0.465 | 0.310 | 0.444 | 0.232 | 0.246 | 0.246 | 0.254 |
| bird1 | 0.321 | 0.017 | — | 0.064 | 0.083 | 0.105 | 0.002 | 0.005 | 0.159 | 0.275 | 0.407 | 0.248 | 0.255 |
| bird2 | 0.970 | 0.141 | — | 0.465 | 1.000 | 0.525 | 0.111 | 0.707 | 0.889 | 0.949 | 1.000 | 1.000 | 0.970 |
| blurBody | 0.991 | 0.090 | — | 0.587 | 0.988 | 0.988 | 0.991 | 0.629 | 0.174 | 0.991 | 0.985 | 0.985 | 0.991 |
| blurCar1 | 0.996 | 0.030 | — | 1.000 | 1.000 | 0.999 | 0.101 | 0.849 | 0.028 | 0.999 | 0.997 | 0.999 | 0.999 |
| blurCar2 | 0.947 | 0.863 | — | 0.947 | 0.947 | 0.938 | 0.950 | 0.998 | 0.144 | 0.947 | 0.947 | 0.944 | 0.947 |
| blurCar3 | 0.997 | 0.252 | — | 0.994 | 1.000 | 1.000 | 0.664 | 0.952 | 0.182 | 1.000 | 0.997 | 1.000 | 1.000 |
| blurCar4 | 1.000 | 0.771 | — | 1.000 | 1.000 | 1.000 | 1.000 | 0.882 | 0.326 | 1.000 | 1.000 | 1.000 | 1.000 |
| blurFace | 1.000 | 0.203 | — | 1.000 | 1.000 | 0.436 | 1.000 | 1.000 | 0.132 | 1.000 | 1.000 | 1.000 | 1.000 |
| blurOwl | 0.960 | 0.071 | — | 0.228 | 0.995 | 0.986 | 0.068 | 0.735 | 0.216 | 0.971 | 0.911 | 0.937 | 0.591 |
| board | 0.947 | 0.605 | — | 0.854 | 0.761 | 0.789 | 0.172 | 0.107 | 0.663 | 0.947 | 0.860 | 0.861 | 0.947 |
| bolt2 | 0.962 | 0.413 | — | 0.007 | 0.007 | 0.041 | 0.010 | 0.007 | 0.007 | 0.826 | 0.758 | 0.007 | 0.007 |
| box | 0.070 | 0.396 | — | 0.357 | 0.339 | 0.234 | 0.355 | 0.760 | 0.176 | 0.071 | 0.133 | 0.289 | 0.356 |
| car1 | 0.054 | 0.999 | — | 0.054 | 0.054 | 0.054 | 0.420 | 0.322 | 0.987 | 0.047 | 0.047 | 0.054 | 0.054 |
| car2 | 1.000 | 1.000 | — | 1.000 | 1.000 | 1.000 | 0.935 | 1.000 | 1.000 | 0.641 | 0.715 | 0.940 | 1.000 |
| car24 | 0.173 | 0.976 | — | 0.173 | 0.173 | 0.170 | 1.000 | 0.483 | 1.000 | 0.173 | 0.173 | 0.163 | 0.173 |
| clifBar | 0.458 | 0.288 | — | 0.305 | 0.610 | 0.091 | 0.094 | 0.073 | 0.061 | 0.172 | 0.339 | 0.114 | 0.271 |
| coupon | 1.000 | 0.382 | — | 1.000 | 0.394 | 1.000 | 1.000 | 0.740 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| crowds | 0.994 | 0.352 | — | 0.997 | 0.879 | 0.769 | 0.115 | 0.994 | 0.735 | 0.986 | 0.988 | 0.991 | 0.988 |
| dancer | 0.907 | 0.929 | — | 0.916 | 0.827 | 0.849 | 0.707 | 0.364 | 0.991 | 0.916 | 0.916 | 0.911 | 0.911 |
| dancer2 | 1.000 | 0.480 | — | 1.000 | 1.000 | 1.000 | 0.993 | 0.853 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| diving | 0.186 | 0.153 | — | 0.186 | 0.172 | 0.181 | 0.126 | 0.167 | 0.177 | 0.186 | 0.186 | 0.186 | 0.186 |
| dog | 0.134 | 0.472 | — | 0.142 | 0.142 | 0.157 | 0.803 | 0.709 | 0.213 | 0.197 | 0.126 | 0.181 | 0.173 |
| dragonBaby | 0.796 | 0.336 | — | 0.310 | 0.805 | 0.088 | 0.195 | 0.257 | 0.230 | 0.708 | 0.770 | 0.770 | 0.735 |
| girl2 | 0.073 | 0.073 | — | 0.070 | 0.686 | 0.199 | 0.161 | 0.080 | 0.232 | 0.073 | 0.073 | 0.075 | 0.073 |
| gym | 0.389 | 0.042 | — | 0.343 | 0.287 | 0.219 | 0.377 | 0.205 | 0.145 | 0.382 | 0.379 | 0.338 | 0.381 |
| human2 | 0.825 | 0.554 | — | 0.183 | 0.472 | 0.699 | 0.281 | 0.525 | 0.546 | 0.646 | 0.811 | 0.883 | 0.853 |
| human3 | 0.279 | 0.005 | — | 0.005 | 0.741 | 0.006 | 0.006 | 0.005 | 0.005 | 0.032 | 0.027 | 0.028 | 0.032 |
| human4 | 0.619 | 0.027 | — | 0.513 | 0.496 | 0.211 | 0.069 | 0.109 | 0.121 | 0.630 | 0.501 | 0.508 | 0.616 |
| human5 | 0.341 | 0.282 | — | 0.237 | 0.341 | 0.341 | 0.282 | 0.512 | 0.415 | 0.243 | 0.241 | 0.244 | 0.243 |
| human6 | 0.223 | 0.437 | — | 0.225 | 0.223 | 0.223 | 0.120 | 0.346 | 0.283 | 0.226 | 0.225 | 0.225 | 0.225 |
| human7 | 0.412 | 0.432 | — | 0.408 | 0.412 | 0.408 | 0.364 | 0.844 | 0.368 | 0.408 | 0.408 | 0.404 | 0.412 |
| human8 | 0.305 | 0.109 | — | 0.305 | 0.305 | 0.133 | 0.109 | 0.133 | 1.000 | 0.305 | 0.305 | 0.305 | 0.305 |
| human9 | 0.239 | 0.125 | — | 0.239 | 0.197 | 0.049 | 0.059 | 0.193 | 0.203 | 0.239 | 0.239 | 0.239 | 0.239 |
| jump | 0.074 | 0.057 | — | 0.074 | 0.082 | 0.098 | 0.057 | 0.074 | 0.074 | 0.057 | 0.033 | 0.098 | 0.074 |
| kiteSurf | 0.429 | 0.286 | — | 0.310 | 0.988 | 0.905 | 0.393 | 0.429 | 0.321 | 0.440 | 0.667 | 0.976 | 1.000 |
| man | 1.000 | 1.000 | — | 1.000 | 1.000 | 1.000 | 0.985 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| panda | 0.509 | 0.431 | — | 0.146 | 0.391 | 0.360 | 0.168 | 0.386 | 0.395 | 0.578 | 0.571 | 0.513 | 0.151 |
| redTeam | 0.375 | 0.957 | — | 0.376 | 0.408 | 0.398 | 0.453 | 0.283 | 0.391 | 0.375 | 0.281 | 0.280 | 0.379 |
| rubik | 0.578 | 0.112 | — | 0.814 | 0.441 | 0.268 | 0.122 | 0.622 | 0.196 | 0.770 | 0.659 | 0.697 | 0.815 |
| skater | 0.869 | 0.650 | — | 0.813 | 0.694 | 0.838 | 0.850 | 0.294 | 0.506 | 0.850 | 0.856 | 0.869 | 0.875 |
| skater2 | 0.798 | 0.154 | — | 0.621 | 0.867 | 0.720 | 0.301 | 0.264 | 0.430 | 0.641 | 0.834 | 0.816 | 0.536 |
| skating2-1 | 0.423 | 0.047 | — | 0.279 | 0.093 | 0.186 | 0.116 | 0.032 | 0.068 | 0.277 | 0.355 | 0.260 | 0.406 |
| skating2-2 | 0.226 | 0.144 | — | 0.279 | 0.197 | 0.330 | 0.030 | 0.027 | 0.438 | 0.190 | 0.378 | 0.230 | 0.226 |
| surfer | 0.423 | 0.521 | — | 0.399 | 0.388 | 0.160 | 0.963 | 0.899 | 0.407 | 0.426 | 0.420 | 0.410 | 0.434 |
| toy | 0.413 | 0.125 | — | 0.432 | 0.362 | 0.491 | 0.974 | 0.738 | 0.221 | 0.380 | 0.402 | 0.395 | 0.391 |
| trans | 0.435 | 0.323 | — | 0.476 | 0.435 | 0.403 | 0.476 | 0.395 | 0.323 | 0.444 | 0.460 | 0.435 | 0.435 |
| twinnings | 0.640 | 0.864 | — | 0.544 | 0.617 | 0.646 | 0.413 | 0.343 | 0.644 | 0.252 | 0.640 | 0.254 | 0.629 |
| vase | 0.159 | 0.122 | — | 0.162 | 0.144 | 0.140 | 0.565 | 0.550 | 0.107 | 0.159 | 0.159 | 0.162 | 0.162 |
| Average | 0.657 | 0.430 | 0.375 | 0.549 | 0.622 | 0.516 | 0.461 | 0.498 | 0.512 | 0.622 | 0.634 | 0.626 | 0.623 |

4. Attribute Based Evaluation

In the manuscript, we show attribute based evaluation in terms of distance precision using one-pass evaluation (OPE) on the benchmark-100 dataset [9]. In this section, we show additional attribute based evaluation in terms of overlap success and distance precision using OPE, temporal robustness evaluation (TRE), and spatial robustness evaluation (SRE) on both the benchmark-100 and the benchmark-50 [8] datasets. As shown in Figures 2-13, the results demonstrate that the proposed HDT algorithm performs favorably against the state-of-the-art trackers.

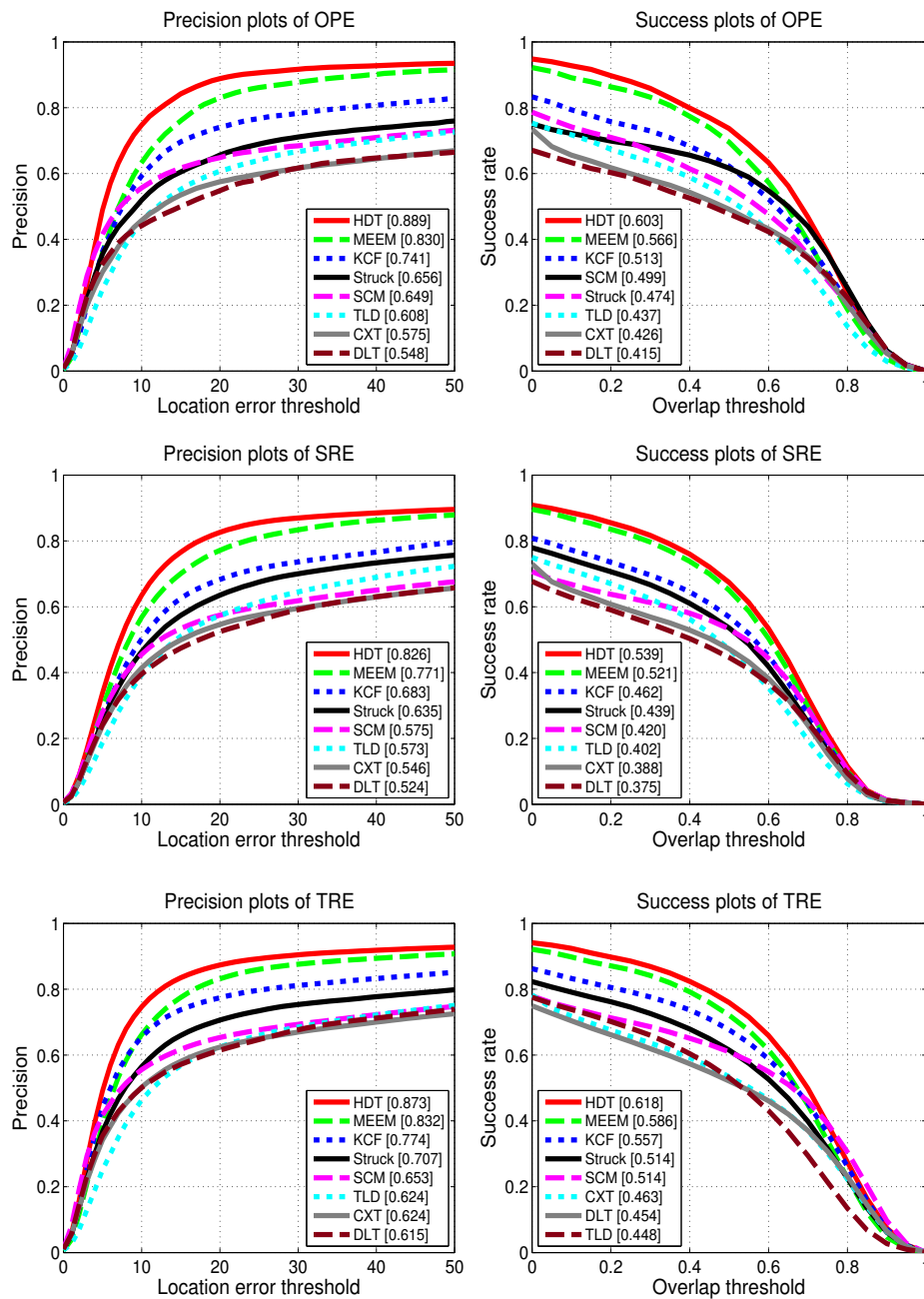


Figure 1. Robustness evaluation tested on the benchmark-50 dataset [8].

References

- [1] K. Chaudhuri, Y. Freund, and D. Hsu. A parameter-free hedging algorithm. In *NIPS*, 2009. 1
- [2] T. B. Dinh, N. Vo, and G. G. Medioni. Context tracker: Exploring supporters and distracters in unconstrained environments. In *CVPR*, 2011. 1
- [3] S. Hare, A. Saffari, and P. H. S. Torr. Struck: Structured output tracking with kernels. In *ICCV*, 2011. 1
- [4] J. F. Henriques, R. Caseiro, P. Martins, and J. Batista. High-speed tracking with kernelized correlation filters. *TPAMI*, 37(3):583–596, 2015. 1
- [5] S. Hong, T. You, S. Kwak, and B. Han. Online tracking by learning discriminative saliency map with convolutional neural network. In *ICML*, 2015. 1
- [6] Z. Kalal, J. Matas, and K. Mikolajczyk. P-N learning: Bootstrapping binary classifiers by structural constraints. In *CVPR*, 2010. 1
- [7] N. Wang and D.-Y. Yeung. Learning a deep compact image representation for visual tracking. In *NIPS*, 2013. 1
- [8] Y. Wu, J. Lim, and M.-H. Yang. Online object tracking: A benchmark. In *CVPR*, 2013. 1, 6, 8, 9, 10, 11, 12, 13
- [9] Y. Wu, J. Lim, and M.-H. Yang. Object tracking benchmark. *TPAMI*, 37(9):1834–1848, 2015. 1, 2, 3, 4, 5, 6, 14, 15, 16, 17, 18, 19
- [10] J. Zhang, S. Ma, and S. Sclaroff. MEEM: robust tracking via multiple experts using entropy minimization. In *ECCV*, 2014. 1
- [11] W. Zhong, H. Lu, and M.-H. Yang. Robust object tracking via sparsity-based collaborative model. In *CVPR*, 2012. 1

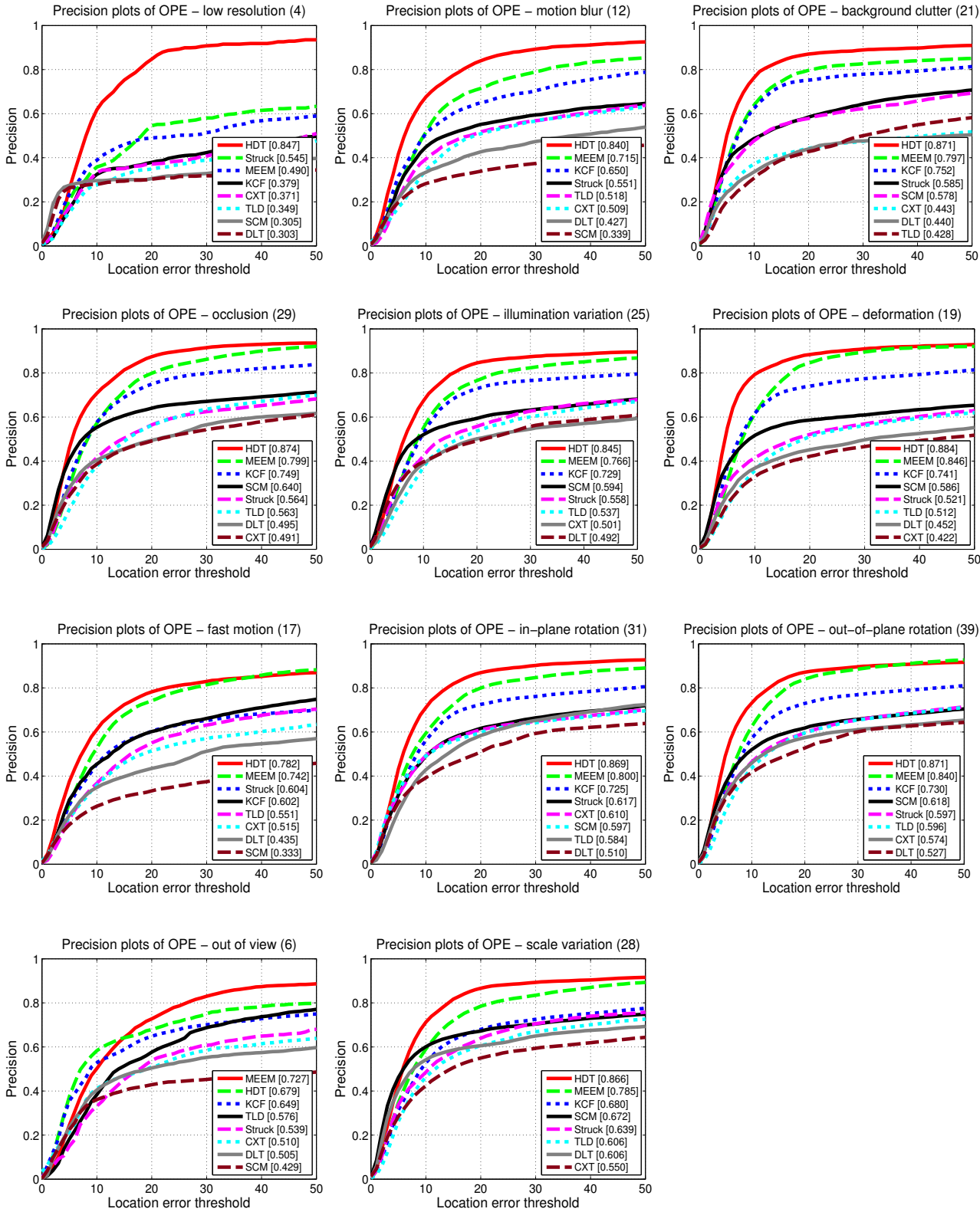


Figure 2. Distance precision plots on the benchmark-50 dataset [8] using one-pass evaluation (OPE) over eleven tracking challenges.

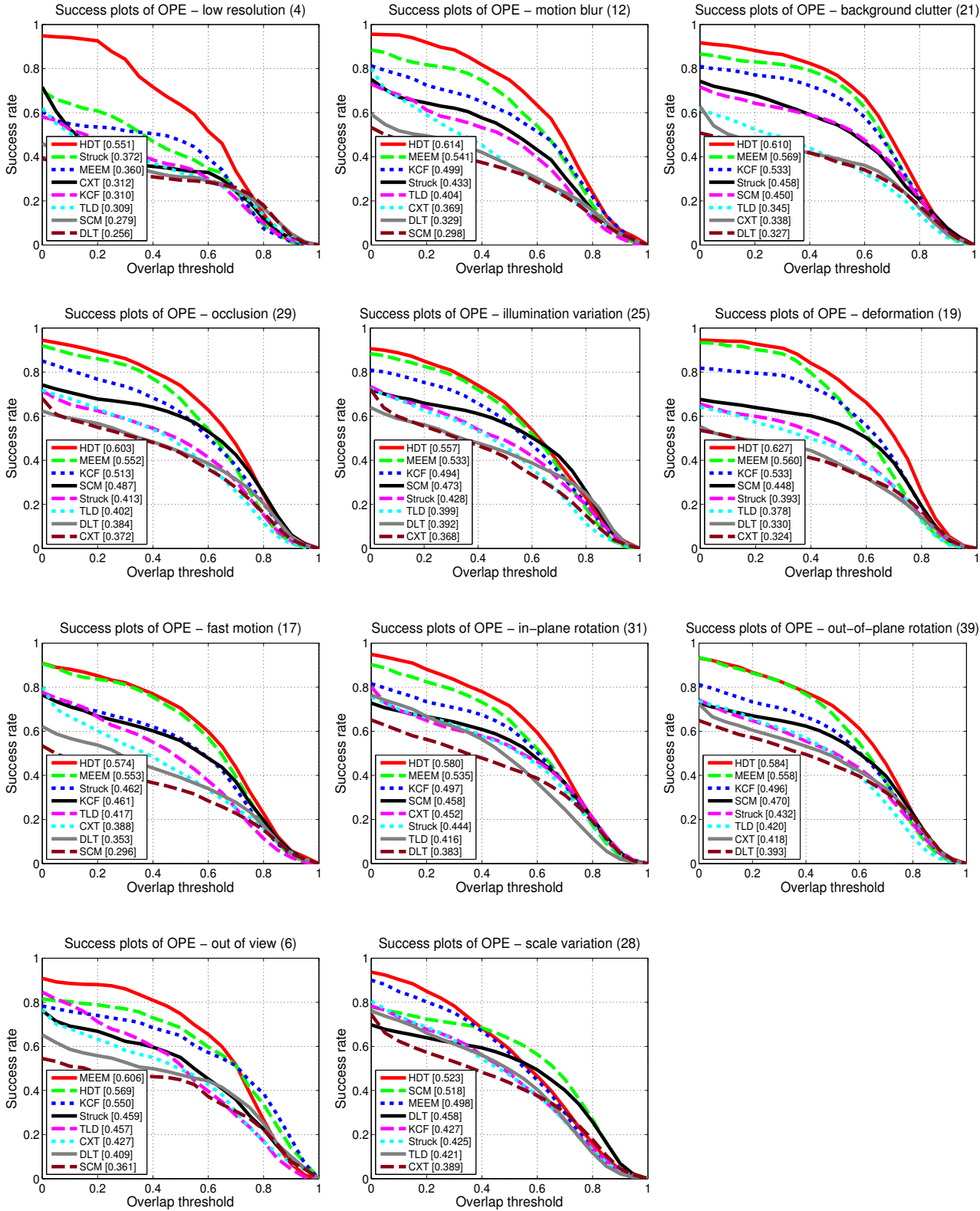


Figure 3. Overlap success plots on the benchmark-50 dataset [8] using one-pass evaluation (OPE) over eleven tracking challenges.

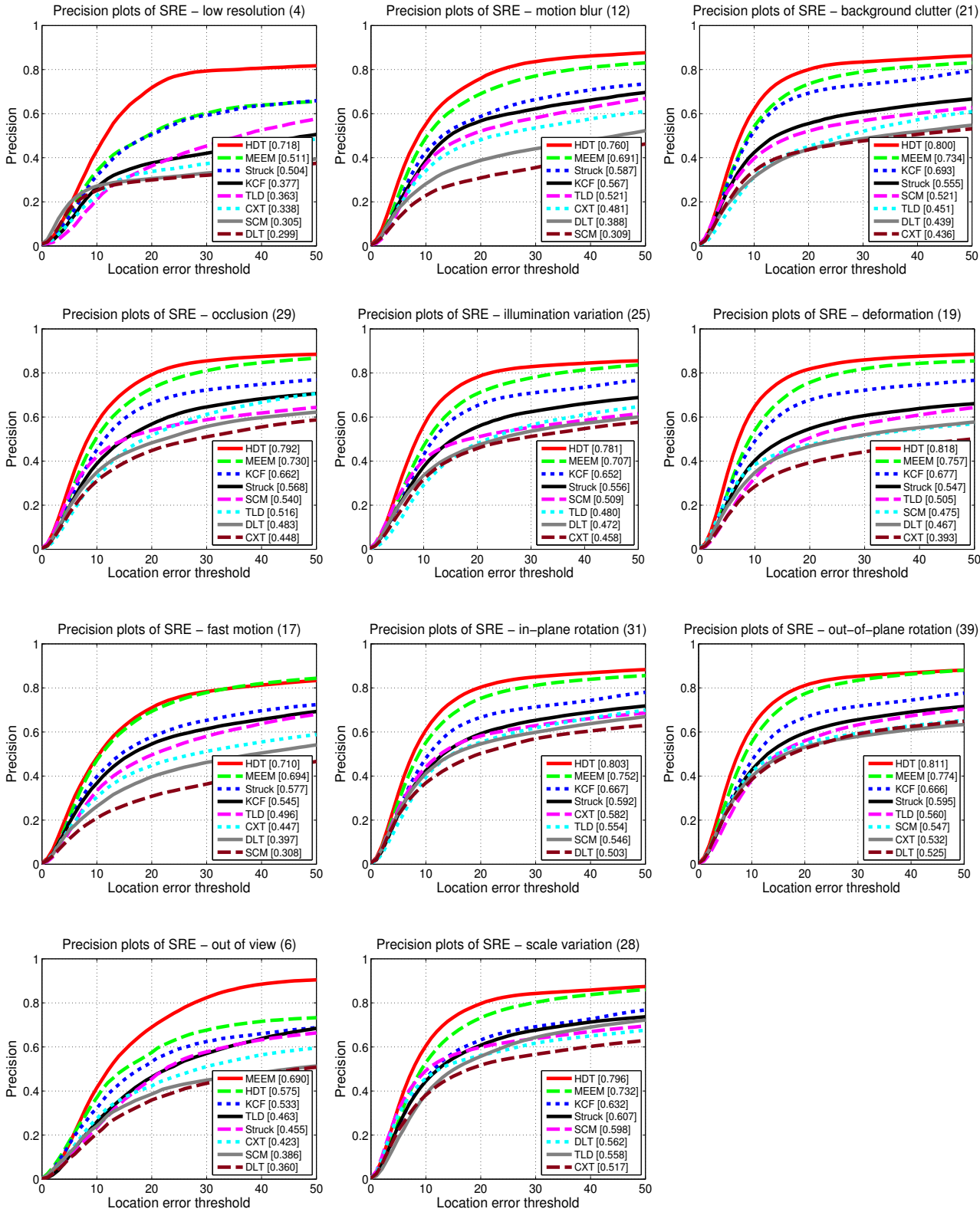


Figure 4. Distance precision plots on benchmark-50 dataset [8] using spatial robustness evaluation (SRE) over eleven tracking challenges.

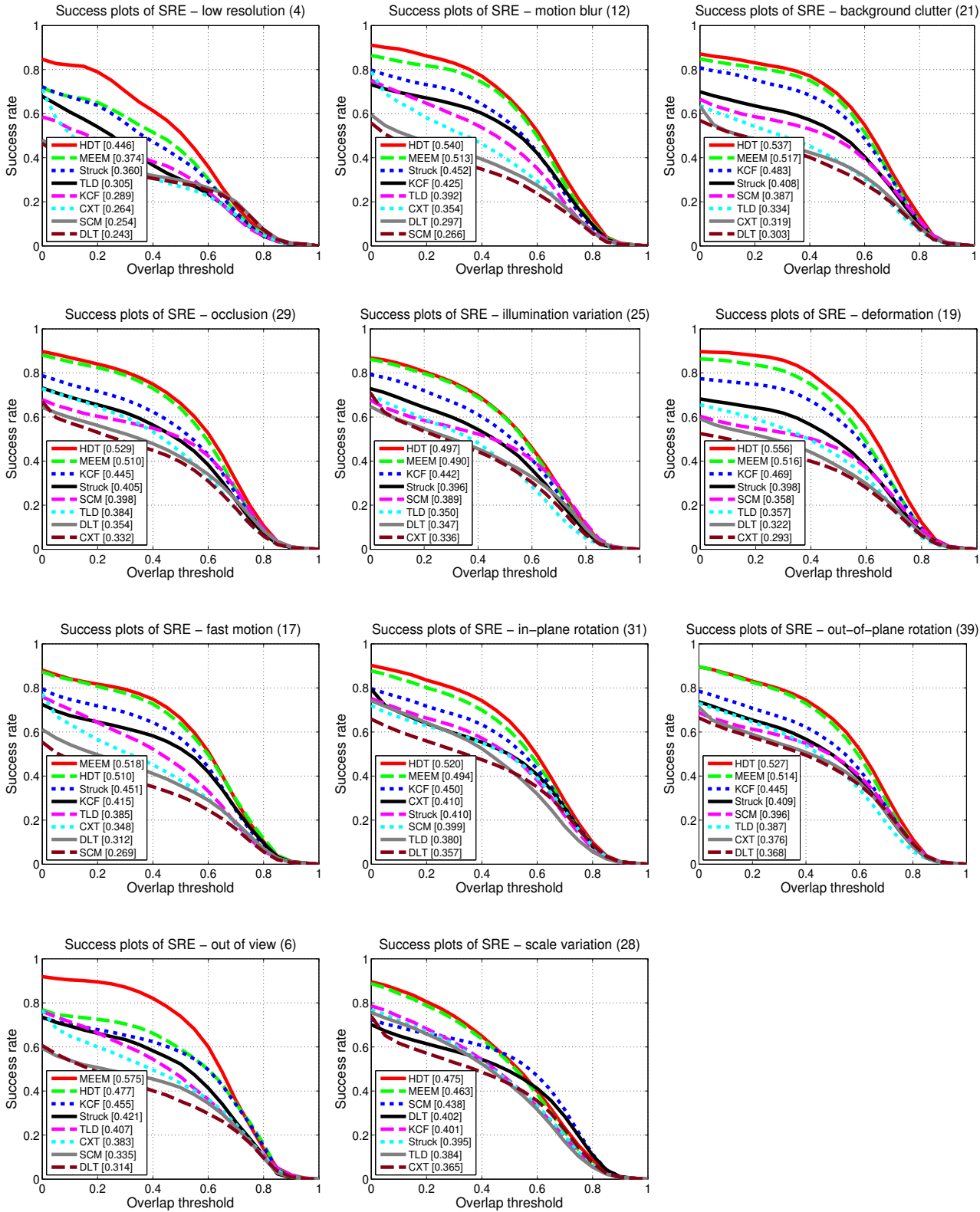


Figure 5. Overlap success plots on the benchmark-50 dataset [8] using spatial robustness evaluation (SRE) over eleven tracking challenges.

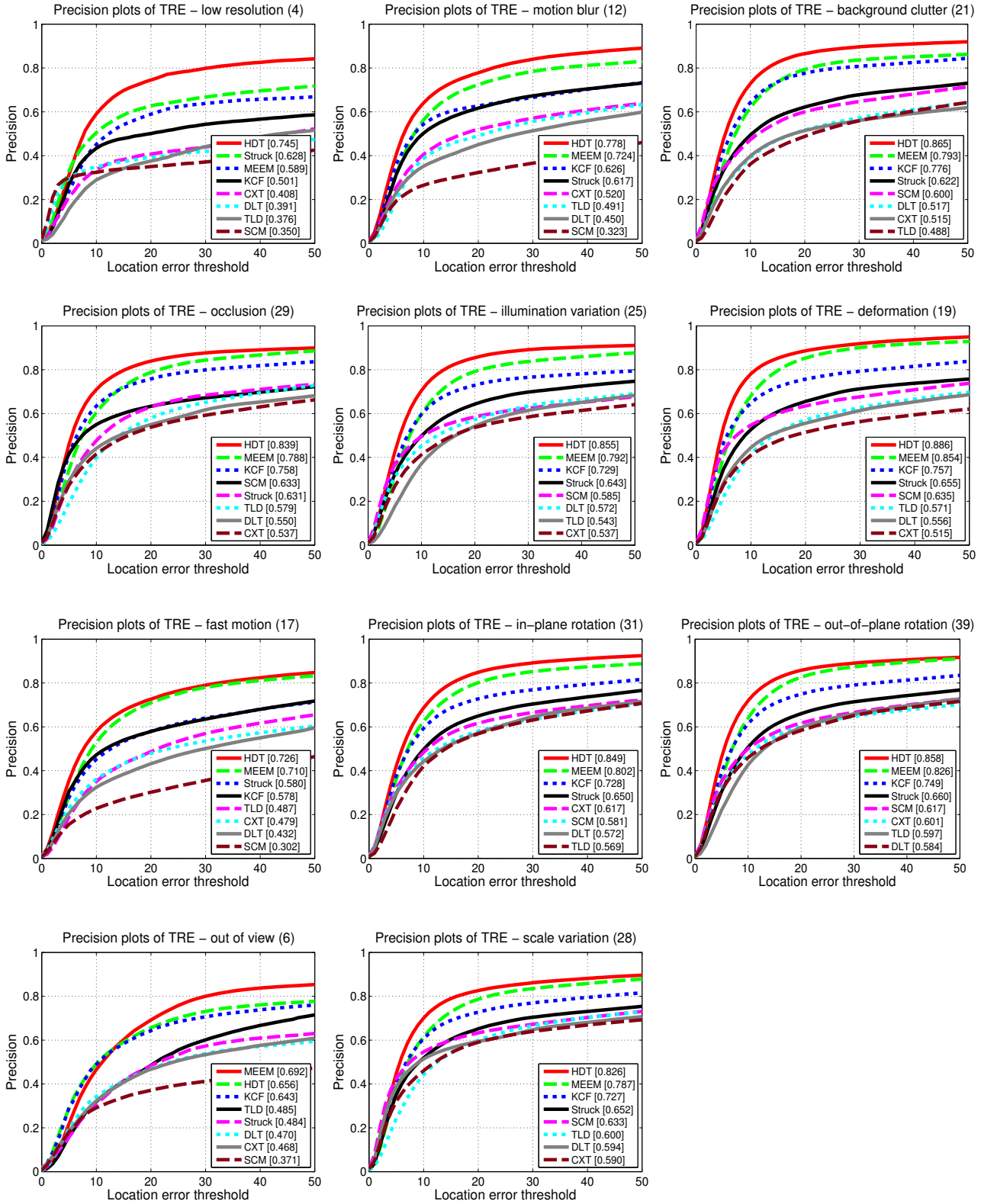


Figure 6. Distance precision plots on the benchmark-50 dataset [8] using temporal robustness evaluation (TRE) over eleven tracking challenges.

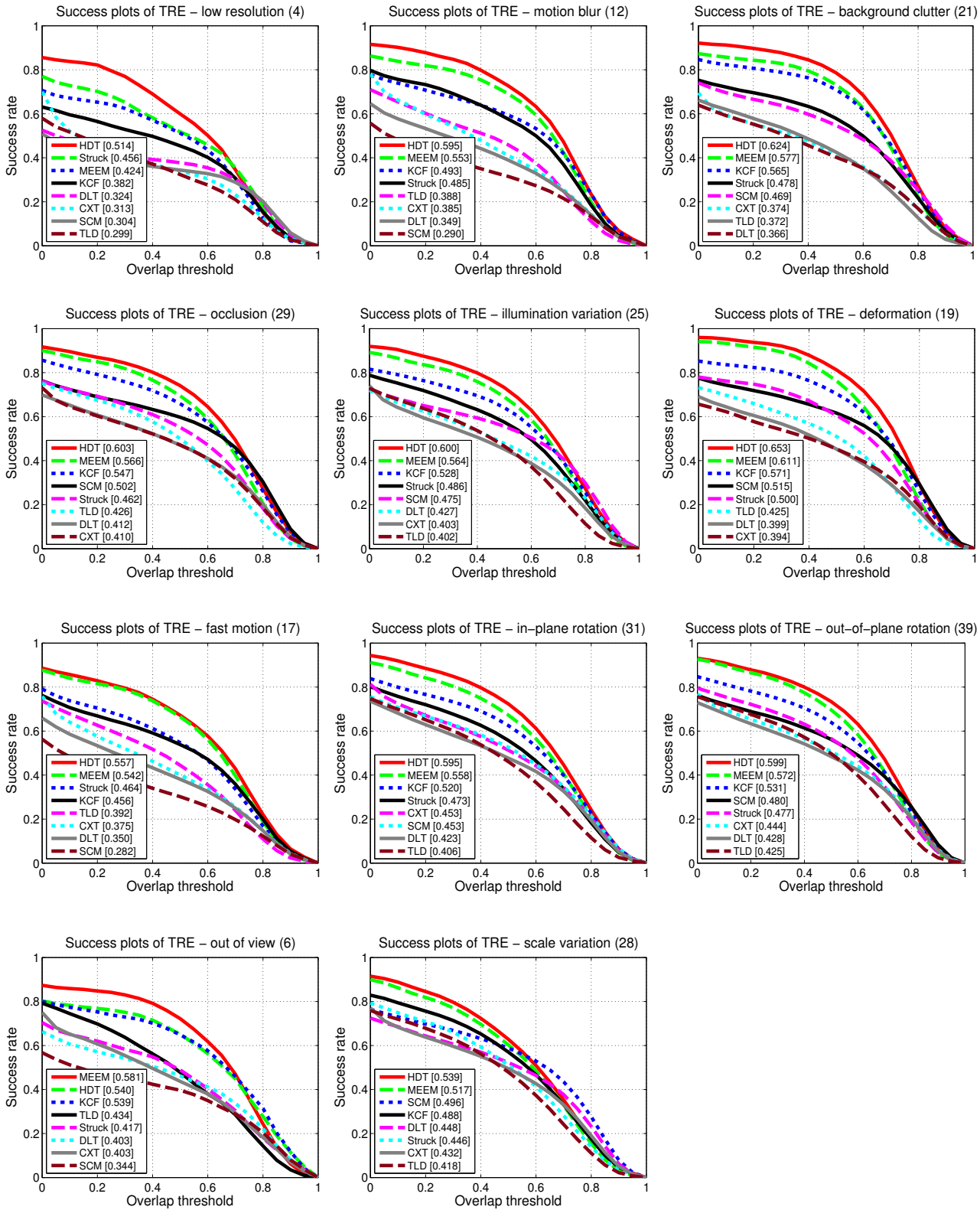


Figure 7. Overlap success plots on the benchmark-50 dataset [8] using temporal robustness evaluation (TRE) over eleven tracking challenges.

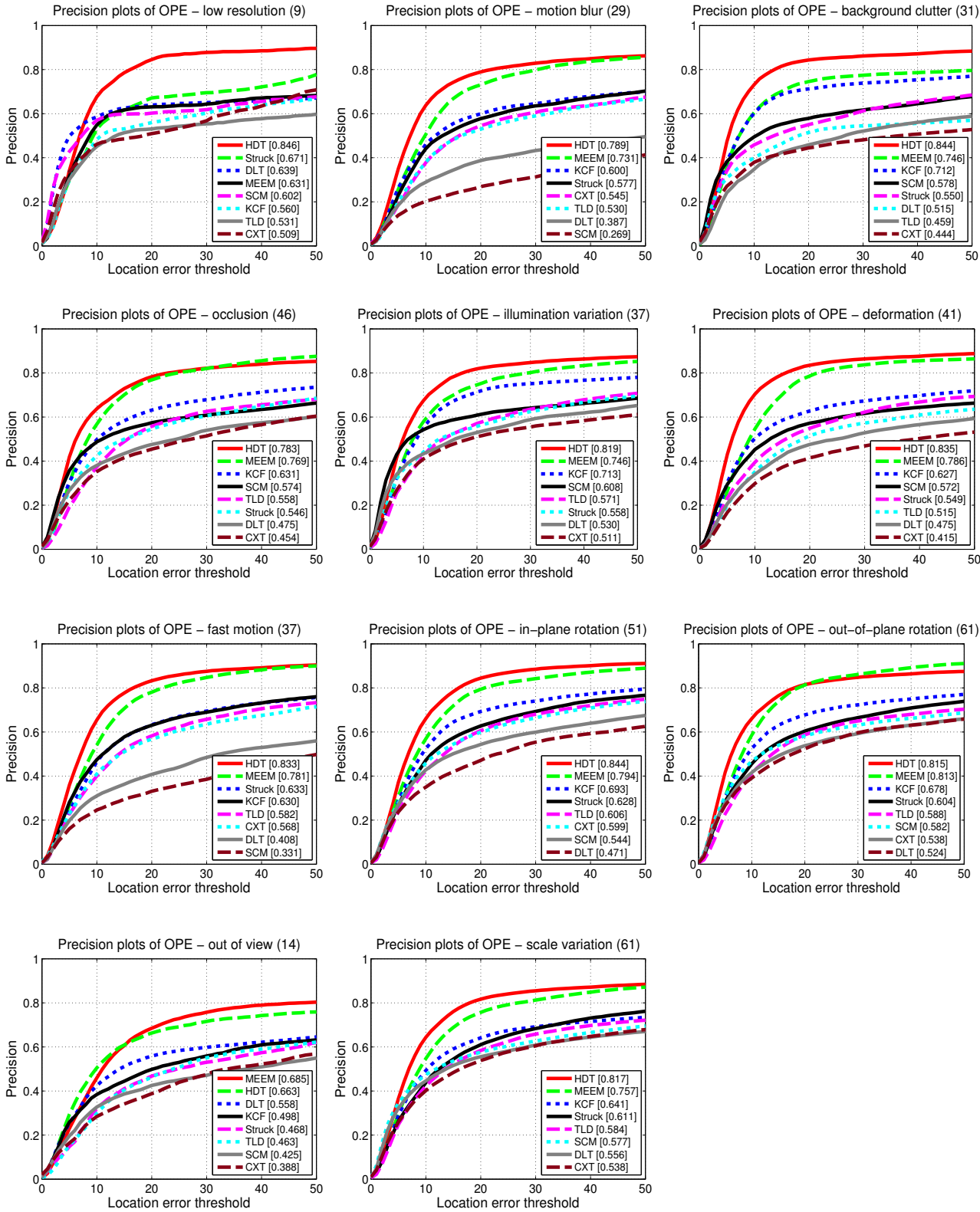


Figure 8. Distance precision plots on the benchmark-100 dataset [9] using one-pass evaluation (OPE) over eleven tracking challenges.

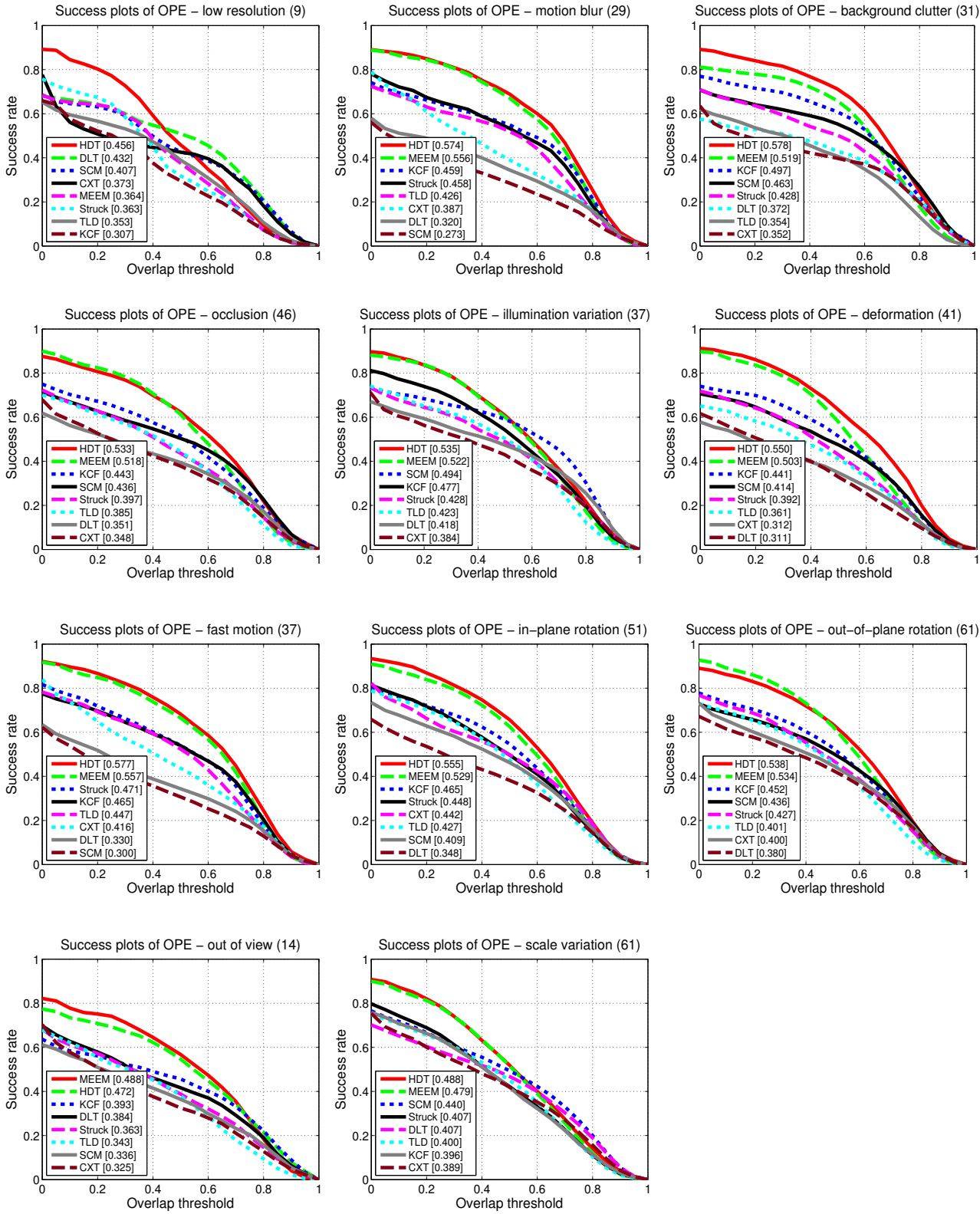


Figure 9. Overlap success plots on the benchmark-100 dataset [9] using one-pass evaluation (OPE) over eleven tracking challenges.

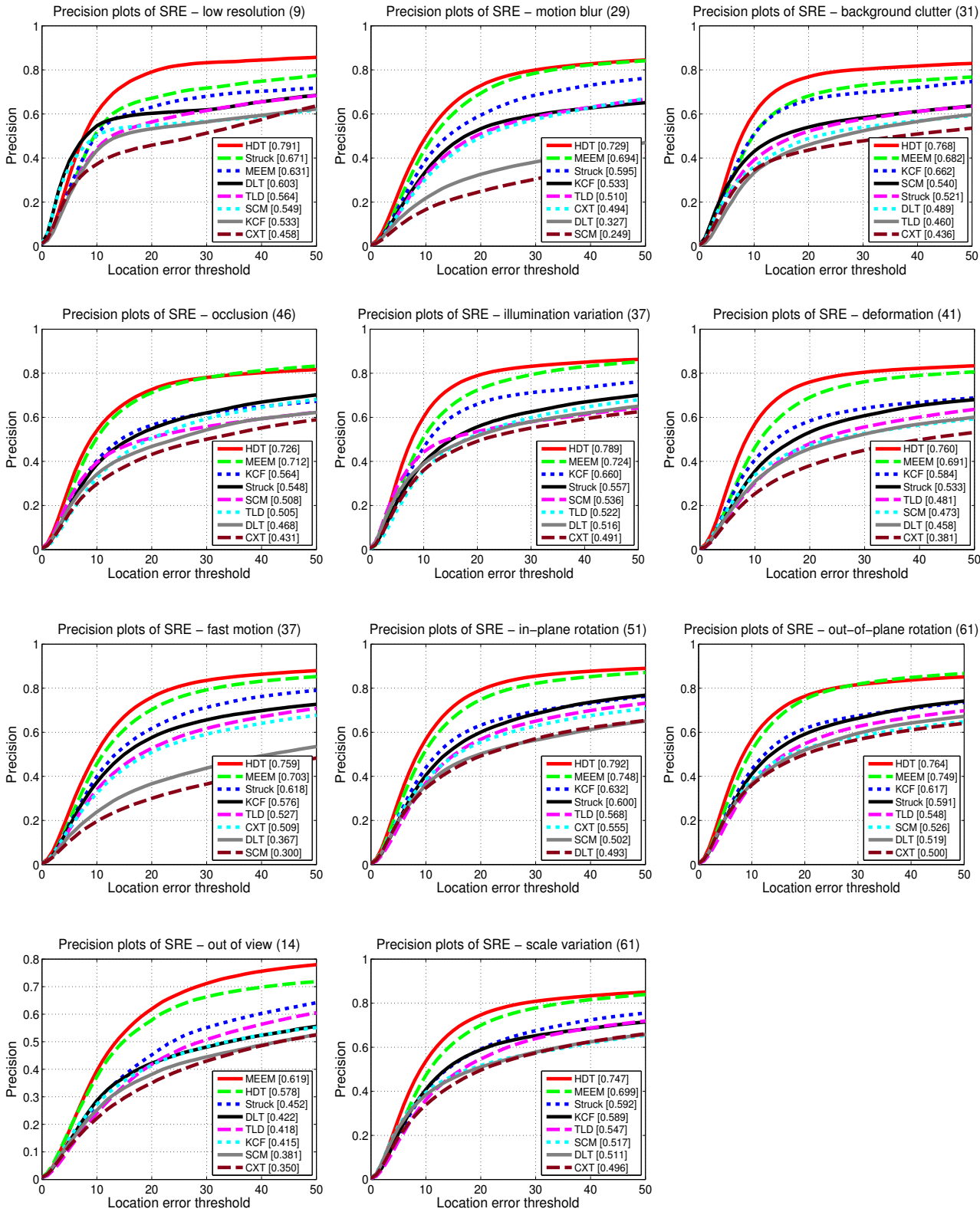


Figure 10. Distance precision plots on the benchmark-100 dataset [9] using spatial robustness evaluation (SRE) over eleven tracking challenges.

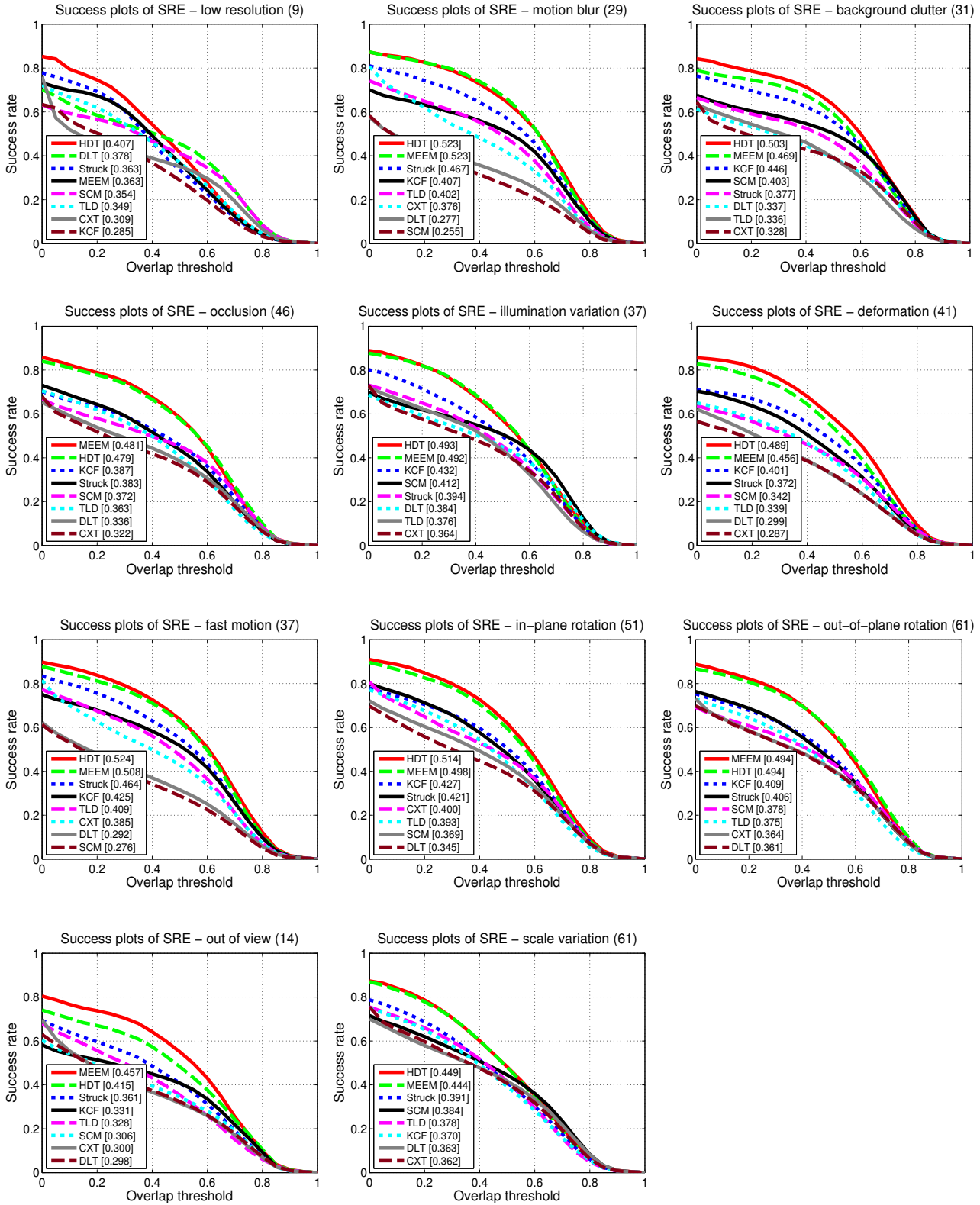


Figure 11. Overlap success plots on the benchmark-100 dataset [9] using spatial robustness evaluation (SRE) over eleven tracking challenges.

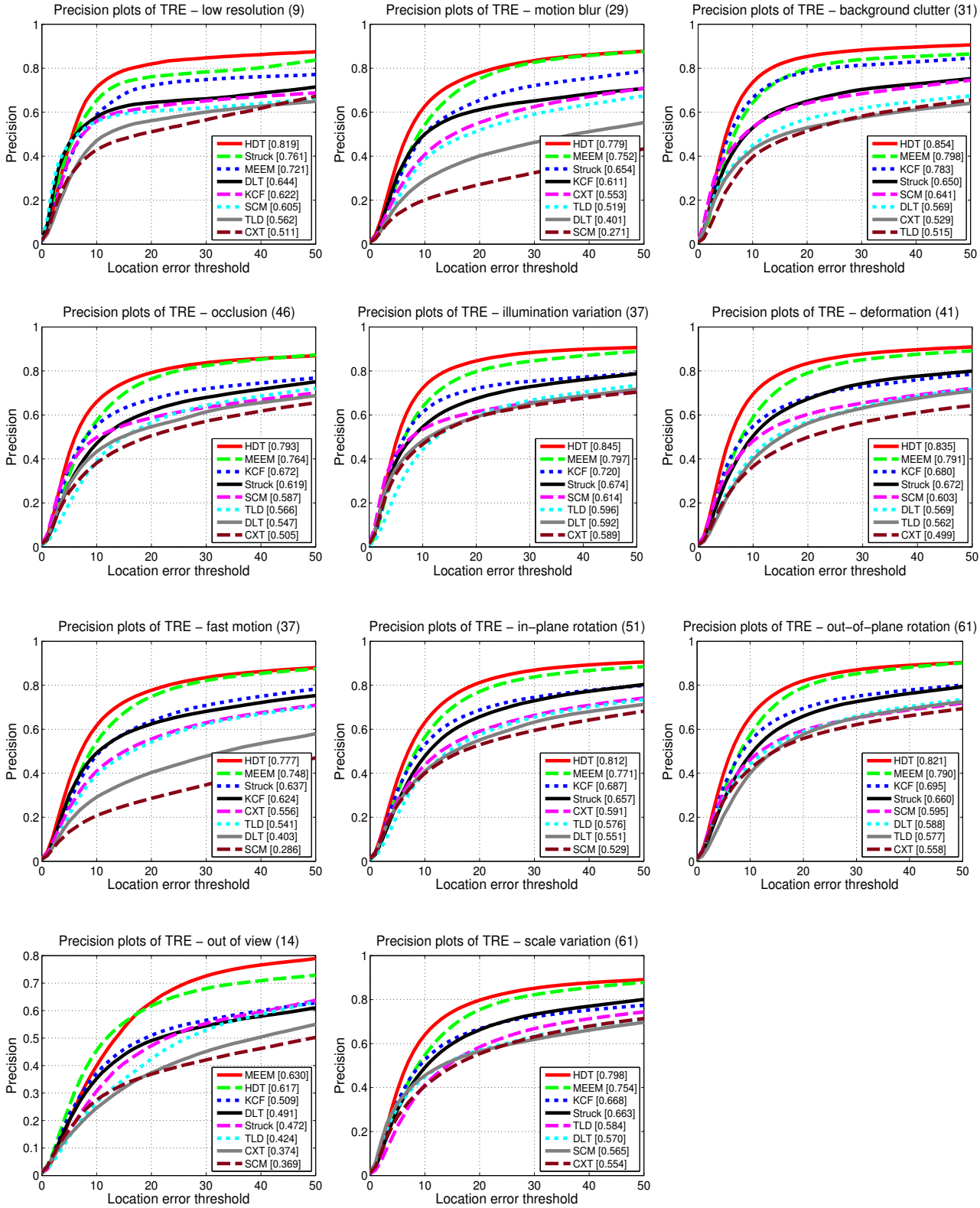


Figure 12. Distance precision plots on the benchmark-100 dataset [9] using temporal robustness evaluation (TRE) over eleven tracking challenges.

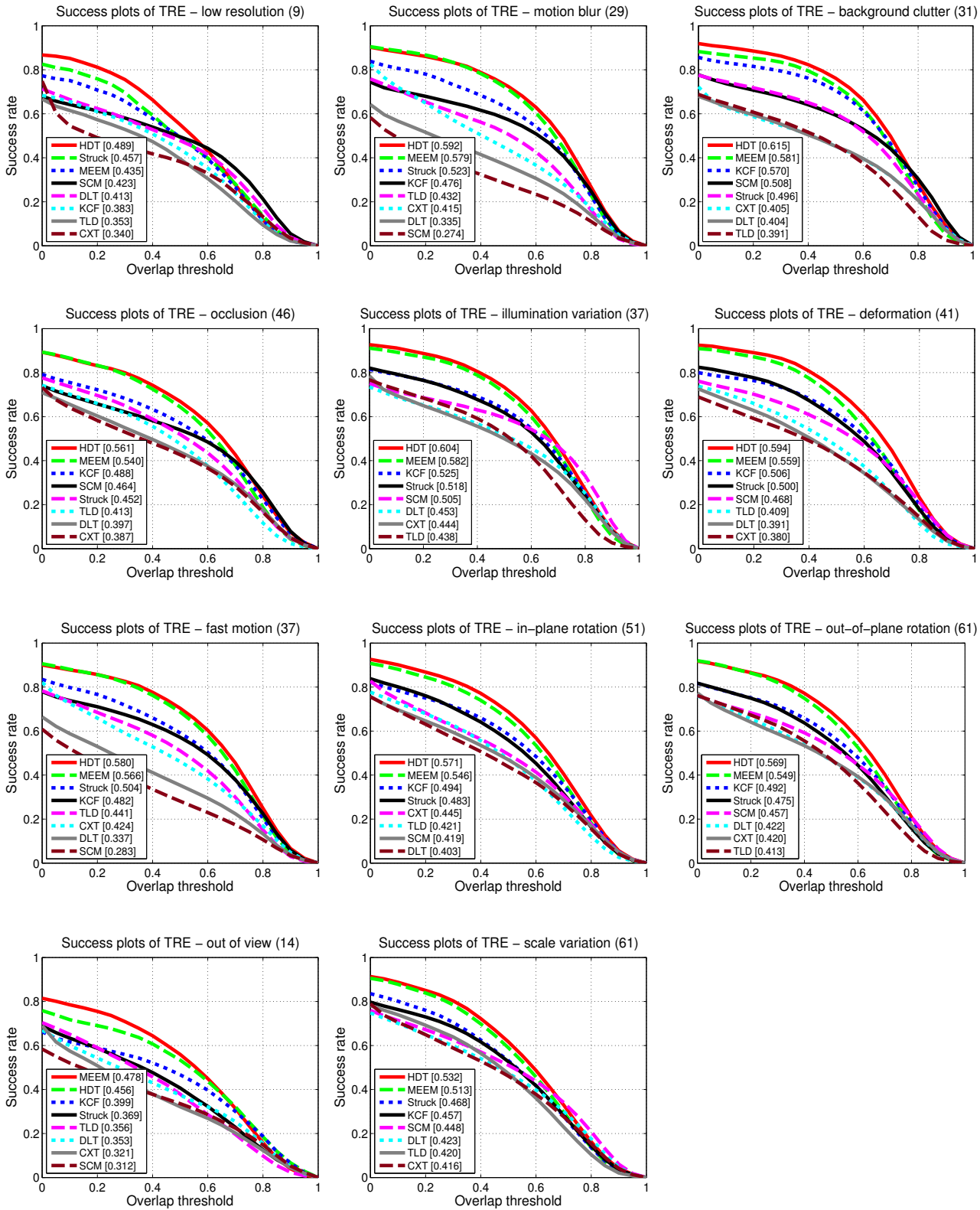


Figure 13. Overlap success plots on the benchmark-100 dataset [9] using temporal robustness evaluation (TRE) over eleven tracking challenges.