Journal of Real-Time Image Processing manuscript No.
(will be inserted by the editor)

CLASP: Energy-Efficient Multi-Person Tracking on CPUs — A Reproducible Accuracy–Latency–Energy Evaluation

Electronic Supplementary Material

Santiago Baquero Delgado

1 Run-level efficiency per setting

All runs of the five reported trackers (1 672 runs). CLASP, ByteTrack, OC-SORT and TrackTrack were measured in the final campaign where listed; DeepSORT, and the competitors of the YOLO11n/s and public settings that were not re-measured, come from the original campaign under the same protocol. Latencies in ms (median over runs of the per-run statistic).

Table 1: Throughput and latency per setting

setting	tracker	campaign	runs	FPS	track p50	track p95	track p99	frame p99	FPS CV
W1 YOLO11m	ByteTrack	final	152	157.94	0.64	0.82	1.19	8.26	0.03
W1 YOLO11m	CLASP	final	152	156.55	0.95	1.64	2.00	8.91	0.04
W1 YOLO11m	DeepSORT	original	152	6.88	112.49	194.49	219.29	224.18	0.01
W1 YOLO11m	OC-SORT	final	152	155.88	0.77	1.06	1.49	8.60	0.05
W1 YOLO11m	TrackTrack	final	152	50.01	15.55	17.79	18.97	25.60	0.03
W2 YOLO11m	ByteTrack	final	14	7.18	0.89	1.10	1.90	156.91	0.01
W2 YOLO11m	CLASP	final	14	7.19	1.51	2.44	3.03	155.93	0.00
W2 YOLO11m	DeepSORT	original	14	2.88	138.69	212.43	250.61	418.10	0.01
W2 YOLO11m	OC-SORT	final	14	7.22	1.06	1.47	2.10	157.08	0.00
W2 YOLO11m	TrackTrack	final	14	6.36	20.87	23.28	24.45	175.90	0.00
FRCNN	ByteTrack	final	22	144.92	0.70	0.92	1.39	9.25	–
FRCNN	CLASP	final	22	141.26	0.77	1.65	2.16	9.63	–
FRCNN	DeepSORT	original	22	6.03	106.84	216.87	259.46	267.63	–
FRCNN	OC-SORT	original	22	145.31	0.95	1.45	1.89	8.88	–
FRCNN	TrackTrack	original	22	52.08	15.07	16.45	17.69	23.70	–
SDP	ByteTrack	final	14	136.36	0.95	1.31	1.67	9.93	–
SDP	CLASP	final	14	134.08	1.47	2.72	3.28	11.08	–
SDP	DeepSORT	original	14	2.73	196.96	346.86	416.04	423.72	–
SDP	OC-SORT	original	14	142.39	1.42	2.12	2.67	9.63	–
SDP	TrackTrack	original	14	50.98	15.36	16.90	17.78	24.00	–
YOLO11s	ByteTrack	final	36	146.21	0.73	0.99	1.27	8.97	–
YOLO11s	CLASP	final	36	141.58	1.09	1.80	2.34	10.14	–
YOLO11s	OC-SORT	original	36	152.57	0.84	1.30	1.73	8.40	–
YOLO11s	TrackTrack	original	36	50.93	15.27	16.90	17.86	24.26	–
YOLO11n	ByteTrack	final	36	155.01	0.68	0.95	1.31	8.28	–
YOLO11n	CLASP	final	36	152.83	0.99	1.70	2.24	8.93	–
YOLO11n	OC-SORT	original	36	144.04	0.81	1.14	1.54	8.93	–
YOLO11n	TrackTrack	original	36	48.20	15.84	18.25	19.50	26.92	–
test	ByteTrack	original	46	159.43	0.63	0.84	1.17	7.94	–
test	CLASP	final	46	131.81	1.02	1.88	2.23	10.55	–
test	DeepSORT	original	46	7.50	110.10	202.53	232.93	239.26	–
test	OC-SORT	original	46	157.69	0.79	1.05	1.48	8.10	–
test	TrackTrack	original	46	50.79	15.06	16.91	17.78	24.25	–
W2 YOLO11n	ByteTrack	final	22	27.58	0.95	1.19	1.89	42.21	0.01
W2 YOLO11n	CLASP	final	22	27.97	1.31	2.26	2.75	42.44	0.01
W2 YOLO11n	OC-SORT	final	22	27.94	1.02	1.33	1.75	42.75	0.01
W2 YOLO11n	TrackTrack	final	22	18.47	20.36	22.78	24.28	63.77	0.02
W2 YOLO11s	ByteTrack	final	14	16.39	0.87	1.07	1.57	75.79	0.01
W2 YOLO11s	CLASP	final	14	16.39	1.51	2.51	3.33	74.87	0.00

S. Baquero Delgado
Universidad de La Salle, Bogotá, Colombia, E-mail: sbaquero66@unisalle.edu.co

setting	tracker	campaign	runs	FPS	track p50	track p95	track p99	frame p99	FPS CV
W2 YOLO11s	OC-SORT	final	14	16.45	1.08	1.46	2.13	72.97	0.01
W2 YOLO11s	TrackTrack	final	14	12.59	20.63	22.82	24.54	95.65	0.00

Table 2: RAPL package energy and resources per setting

setting	tracker	gross mJ/fr.	net mJ/fr.	CI lo	CI hi	CPU	
W1 YOLO11m	ByteTrack	189.50	120.55	110.48	127.69	97.94	0.36
W1 YOLO11m	CLASP	194.18	124.44	113.66	131.04	98.48	0.37
W1 YOLO11m	DeepSORT	6987.72	5700.81	5110.36	6401.44	389.28	2.50
W1 YOLO11m	OC-SORT	190.08	119.91	110.04	126.88	97.88	0.39
W1 YOLO11m	TrackTrack	729.51	510.92	479.50	537.61	152.47	0.37
W2 YOLO11m	ByteTrack	9186.63	7271.14	6830.65	7859.77	390.20	0.59
W2 YOLO11m	CLASP	9160.66	7245.18	6801.23	7826.17	390.62	0.60
W2 YOLO11m	DeepSORT	19800.78	15644.89	13622.05	17538.85	390.63	2.26
W2 YOLO11m	OC-SORT	9110.24	7203.60	6759.51	7776.06	390.57	0.62
W2 YOLO11m	TrackTrack	9969.27	7807.10	7360.59	8350.43	390.37	0.59
FRCNN	ByteTrack	200.23	125.91	108.24	143.17	96.98	0.36
FRCNN	CLASP	205.80	129.89	110.82	148.06	96.93	0.37
FRCNN	DeepSORT	8277.75	6613.21	3943.16	10770.95	386.20	3.67
FRCNN	OC-SORT	198.52	125.84	105.36	137.06	97.45	0.40
FRCNN	TrackTrack	697.12	494.13	451.84	569.21	152.79	0.36
SDP	ByteTrack	213.41	122.05	96.89	154.16	95.37	0.36
SDP	CLASP	217.66	126.44	104.13	151.13	95.93	0.38
SDP	DeepSORT	17897.19	14502.49	6673.52	19170.87	383.56	3.92
SDP	OC-SORT	206.37	137.36	105.62	167.20	96.96	0.41
SDP	TrackTrack	713.14	519.51	441.64	589.25	154.15	0.38
YOLO11s	ByteTrack	195.70	114.72	102.44	125.77	96.78	0.36
YOLO11s	CLASP	205.70	122.48	110.54	135.98	96.68	0.37
YOLO11s	OC-SORT	184.00	127.42	112.51	135.52	97.64	0.39
YOLO11s	TrackTrack	688.59	518.48	476.86	554.53	152.07	0.38
YOLO11n	ByteTrack	202.92	131.49	117.59	143.11	98.68	0.36
YOLO11n	CLASP	199.34	127.05	118.28	147.82	99.33	0.37
YOLO11n	OC-SORT	201.30	127.71	114.54	145.98	97.42	0.39
YOLO11n	TrackTrack	713.49	490.57	455.01	533.26	148.81	0.38
test	ByteTrack	188.86	121.81	111.82	132.95	97.23	0.34
test	CLASP	223.82	127.62	116.35	143.31	94.56	0.37
test	DeepSORT	6754.51	5324.83	4710.89	6329.56	389.02	3.04
test	OC-SORT	189.62	121.95	113.42	134.24	97.52	0.38
test	TrackTrack	745.46	535.30	507.76	573.20	150.66	0.36
W2 YOLO11n	ByteTrack	2043.18	1656.20	1549.67	1675.11	388.95	0.45
W2 YOLO11n	CLASP	2046.66	1665.10	1564.33	1707.99	390.30	0.46
W2 YOLO11n	OC-SORT	2027.54	1646.20	1541.57	1663.25	389.45	0.49
W2 YOLO11n	TrackTrack	2941.81	2367.22	2216.40	2443.64	389.14	0.47
W2 YOLO11s	ByteTrack	3811.19	3005.81	2896.44	3095.00	389.58	0.49
W2 YOLO11s	CLASP	3856.21	3050.86	2962.41	3137.01	389.79	0.51
W2 YOLO11s	OC-SORT	3840.42	3038.58	2923.40	3138.76	389.94	0.53
W2 YOLO11s	TrackTrack	4742.71	3693.10	3601.78	3799.24	389.44	0.49

2 W1 by dataset

Table 3: W1 by dataset (final campaign): throughput, tracking latency percentiles (ms) and gross RAPL energy per frame

dataset	split	tracker	runs	fps	p50	p95	p99	gross_mJ
DanceTrack	train	ByteTrack	80	148.12	0.60	0.78	1.04	180.55
DanceTrack	train	CLASP	80	147.13	0.95	1.63	1.97	187.73
DanceTrack	train	OC-SORT	80	145.48	0.75	1.02	1.41	184.45
DanceTrack	train	TrackTrack	80	45.91	15.47	17.57	18.85	721.73
DanceTrack	val	ByteTrack	50	152.75	0.64	0.80	1.09	185.26
DanceTrack	val	CLASP	50	143.17	0.93	1.62	1.96	193.70

dataset	split	tracker	runs	fps	p50	p95	p99	gross_mJ
DanceTrack	val	OC-SORT	50	146.40	0.79	1.05	1.46	190.14
DanceTrack	val	TrackTrack	50	45.16	15.44	17.87	18.99	717.86
MOT17	train	ByteTrack	14	140.43	0.78	1.00	1.42	191.96
MOT17	train	CLASP	14	135.06	1.28	2.13	2.58	201.70
MOT17	train	OC-SORT	14	140.13	0.92	1.33	1.83	192.75
MOT17	train	TrackTrack	14	44.95	15.93	17.73	18.98	755.47
MOT20	train	ByteTrack	8	115.96	1.06	1.40	1.77	242.06
MOT20	train	CLASP	8	127.50	0.92	1.51	1.89	221.23
MOT20	train	OC-SORT	8	125.76	0.81	1.16	1.56	214.70
MOT20	train	TrackTrack	8	42.71	16.04	18.02	20.14	783.71

3 Paired bench of the final CLASP

v2 = CLASP-Ref (final model, reference path); f_s_* = cumulative exact mechanisms; clasp = certified CLASP. Frame-level identity with the reference: bytetrack 0/2283, clasp 2283/2283, f_s_E1 2283/2283, f_s_E12 2283/2283, f_s_E123 2283/2283, f_s_E1234 2283/2283, f_s_E1234T 2283/2283, oc-sort 0/2283, tracktrack 0/2283, v2 2283/2283.

Table 4 Final-campaign paired bench (8 sequences x 300 frames, 7 rounds x 3 passes)

variant	ms/fr.	mJ/fr.	time ratio	energy ratio	CI lo	CI hi	p	lower (of 8)
CLASP-Ref	1.434	39.364	1.000	1.000	1.000	1.000	–	–
+E1	1.212	32.067	0.842	0.813	0.743	0.859	0.008	8.000
+E1 E2	1.099	30.230	0.766	0.766	0.716	0.790	0.008	8.000
+E1 E2 E3	1.229	34.683	0.858	0.880	0.815	0.908	0.008	8.000
+E1 E2 E3 E4	1.153	31.801	0.801	0.798	0.714	0.817	0.008	8.000
+E1 E2 E3 E4 T	1.002	27.583	0.687	0.690	0.577	0.732	0.008	8.000
CLASP (E2 E3 E4 T)	0.995	26.571	0.681	0.660	0.559	0.726	0.008	8.000
bytetrack	0.675	19.258	0.456	0.476	0.384	0.566	0.008	8.000
oc-sort	0.716	19.689	0.496	0.494	0.427	0.551	0.008	8.000
tracktrack	19.637	613.482	13.524	15.346	12.188	17.796	0.008	0.000

4 Certificate yield versus appearance weight

Operation counts on the 8 bench sequences (300 frames each) for the final CLASP with w_a varied; identical = output of the certified implementation equal to the reference at every frame.

Table 5 Certificate yield versus w_a

w_a	components	certified	fraction	hist. certified	hist. reference	hist. ratio	identical
0.100	6 531	5 671	0.868	5 726	13 793	0.415	1
0.200	6 545	5 459	0.834	6 055	13 929	0.435	1
0.300	6 598	5 208	0.789	6 393	14 069	0.454	1
0.400	6 649	4 843	0.728	6 865	14 267	0.481	1
0.500	6 691	4 051	0.605	7 763	14 359	0.541	1
0.600	6 723	1 662	0.247	9 904	14 735	0.672	1
0.650	6 802	48	0.007	11 238	14 912	0.754	1
0.700	6 829	0	0.000	11 281	15 036	0.750	1
0.800	6 859	0	0.000	11 300	15 263	0.740	1

5 Cost of each mechanism of the final CLASP

Table 6 Paired bench of the ablation variants (reference path; 5 rounds x 3 passes); ratios to the full model (v2)

variant	ms/fr.	mJ/fr.	ratio	CI lo	CI hi	p
v2	1.426	40.096	1.000	1.000	1.000	–
clasp	0.997	27.166	0.666	0.595	0.734	0.008
no cascade	2.101	56.389	1.435	1.290	1.600	0.008
no acceptance threshold	1.307	35.384	0.914	0.880	0.960	0.008
fixed gate	0.829	22.283	0.580	0.490	0.682	0.008
no appearance	0.856	24.072	0.591	0.484	0.738	0.008
no hysteresis	1.394	37.563	0.965	0.907	1.025	0.148
fixed hysteresis 10	1.425	38.807	0.993	0.943	1.042	0.312
velocity prediction	2.273	61.016	1.530	1.336	1.740	0.008
no identity inheritance	1.428	39.007	0.966	0.930	1.001	0.547
no duplicate rescue	1.429	39.139	0.997	0.962	1.034	0.547
greedy assignment	1.434	39.930	1.008	0.959	1.060	0.945
no lost memory reid	1.386	37.895	0.960	0.914	1.018	0.109
no virtual fill	1.423	38.062	0.980	0.941	1.014	0.148
no track aware init	1.440	40.037	1.016	0.971	1.063	1.000
appearance weight 03	1.359	36.854	0.930	0.869	0.995	0.109
lite	1.401	37.439	0.988	0.948	1.036	0.148

6 Frozen operating point ($w_a = 0.3$): exact mechanisms

Design-phase paired bench of the frozen CLASP (8 sequences, 7 rounds x 5 passes): cumulative (s E*) and leave-one-out (loo *) variants; v2 = frozen CLASP-Ref. At this operating point the certificate is the largest single contribution (removing it raises energy by 28%).

Table 7 Frozen CLASP: cumulative and leave-one-out bench

variant	ms/frame	mJ/frame	time ratio	energy ratio	p (Wilcoxon)	seq. lower (of 8)
v2	1.383	35.688	1.000	1.000	–	–
s E1	1.178	30.274	0.847	0.847	0.016	7.000
s E12	1.078	26.628	0.779	0.751	0.008	8.000
s E123	0.896	23.254	0.648	0.654	0.008	8.000
s E1234	0.821	21.049	0.596	0.594	0.008	8.000
s E1234T	0.675	17.620	0.488	0.496	0.008	8.000
s E1234T A1	0.576	15.214	0.415	0.426	0.008	8.000
s E1234T A2	0.573	14.898	0.415	0.421	0.008	8.000
loo noE1	0.668	16.629	0.483	0.468	0.008	8.000
loo noE2	0.705	18.165	0.509	0.511	0.008	8.000
loo noE3	0.863	22.045	0.608	0.600	0.008	8.000
loo noPre	0.751	19.062	0.545	0.536	0.008	8.000
bytetrack	0.717	17.902	0.500	0.491	0.008	8.000

7 Pilot with additional trackers

Nine design-disjoint sequences; Ultralytics implementations of BoT-SORT, Deep OC-SORT and FastTrack at default settings (no ReID); thresholds not calibrated; run before the revision (frozen CLASP).

Table 8: Pilot: accuracy and wall time per frame of additional trackers

tracker	HOTA	AssA	DetA	IDF1	IDSW	ms/frame	HOTA MOT17	HOTA MOT20	HOTA DT
CLASP (frozen)	44.23	40.75	52.18	49.49	465	0.75	40.97	30.62	53.47
botsort	44.05	40.54	52.84	48.24	339	17.24	42.56	30.05	52.17
tracktrack	38.92	40.38	46.05	40.00	174	17.31	36.71	17.70	51.18
fasttrack	38.64	35.82	47.81	44.97	511	0.98	40.68	30.14	41.36
bytetrack	38.06	34.65	47.66	43.79	501	0.86	39.25	29.26	41.57
ocsort	38.02	35.27	46.46	43.79	545	1.20	39.96	26.29	42.43
deepocsort	37.47	34.70	46.08	42.72	508	1.29	39.87	24.10	42.34
DeepSORT	37.37	34.45	47.30	43.71	545	–	42.92	26.41	38.69

8 Tracker share of system energy by detector scale

Graphical form of the detector-scale table of the main text.

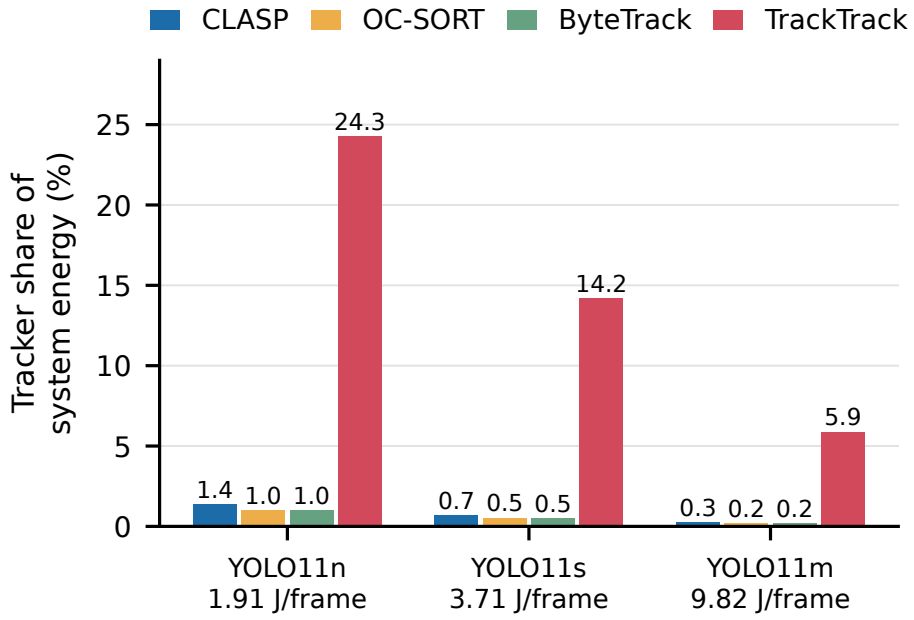


Fig. S1 Tracker share of system energy as a function of detector scale (RAPL package; detector cost measured when building the detection caches, tracker cost from the paired bench)

9 Energy regression between the versions of CLASP

Paired RAPL bench (8 sequences × 300 frames, 7 rounds × 3 passes). Reference v2 = frozen CLASP, certified; frozen_ref / final_ref / lite_ref = reference code paths; final, lite, custody = certified path. Median over rounds of the energy per frame divided by that of v2 in the same sequence.

10 Per-frame deadline compliance per sequence

YOLO11n in the loop, MOT17 train, every run (fresh pinned process; miss40 / miss33 = % of frames above 40 / 33.3 ms).

Table 9 Energy ratio to the frozen certified CLASP per sequence

sequence	bytetrack	custody	final	final_ref	frozen_ref	lite	lite_ref	oc-sort	v2
MOT17-02-FRCNN	1.157	1.685	1.277	1.992	1.937	1.376	1.946	1.026	1.000
MOT17-04-FRCNN	1.508	1.377	1.040	1.978	2.095	1.065	2.062	1.416	1.000
MOT17-05-FRCNN	0.970	1.879	1.567	2.437	2.064	1.590	2.344	1.331	1.000
MOT17-09-FRCNN	0.894	1.714	1.580	2.141	1.919	1.524	2.109	1.031	1.000
MOT20-01	1.659	1.483	1.234	2.151	1.961	1.063	2.047	1.427	1.000
dancetrack0043	0.669	1.868	1.665	2.211	2.321	1.562	2.328	0.904	1.000
dancetrack0052	0.572	1.714	1.516	1.956	2.039	1.533	1.962	0.824	1.000
dancetrack0073	0.616	1.454	1.248	1.897	1.675	1.432	1.750	0.701	1.000

Table 10: Complete pipeline with YOLO11n, every run

tracker	sequence	repeat	fps	p50	p95	p99	miss40	miss33	J_frame	cores	GB
bytetrack	MOT17-02	1	27.38	34.79	46.01	66.59	12.67	74.00	2.58	3.80	0.46
bytetrack	MOT17-02	2	29.81	32.99	37.54	41.95	2.17	41.33	1.89	3.86	0.46
clasp	MOT17-02	1	27.10	35.08	45.38	65.96	15.00	78.33	2.75	3.84	0.49
clasp	MOT17-02	2	30.16	32.71	37.13	40.36	1.67	34.33	1.82	3.90	0.49
clasp-lite	MOT17-02	1	30.54	32.24	35.43	37.62	0.50	25.33	1.95	3.92	0.49
clasp-lite	MOT17-02	2	29.69	33.05	37.68	41.32	2.17	44.50	2.02	3.88	0.49
oc-sort	MOT17-02	1	29.79	32.93	37.75	41.59	2.33	40.00	2.23	3.91	0.50
oc-sort	MOT17-02	2	30.27	32.30	36.60	41.37	1.50	26.83	1.88	3.87	0.50
polytrack-x	MOT17-02	1	30.66	32.12	36.09	38.06	0.00	26.83	1.95	3.92	0.49
polytrack-x	MOT17-02	2	29.90	32.93	37.30	41.60	1.67	42.50	1.95	3.88	0.49
tracktrack	MOT17-02	1	18.93	52.76	57.51	60.03	100.00	100.00	2.86	3.90	0.47
tracktrack	MOT17-02	2	19.17	51.93	56.54	60.22	100.00	100.00	2.79	3.89	0.47
bytetrack	MOT17-04	1	29.73	33.17	37.26	40.23	1.24	46.38	1.90	3.90	0.46
bytetrack	MOT17-04	2	29.22	33.83	37.78	40.84	1.71	61.33	1.93	3.90	0.46
clasp	MOT17-04	1	29.60	33.30	37.60	41.16	1.52	49.33	1.91	3.88	0.49
clasp	MOT17-04	2	29.72	33.22	37.51	40.64	1.24	47.33	1.88	3.90	0.49
clasp-lite	MOT17-04	1	29.34	33.37	37.79	43.52	1.81	50.57	2.02	3.88	0.49
clasp-lite	MOT17-04	2	29.71	33.10	37.64	42.21	1.62	44.86	1.87	3.90	0.49
oc-sort	MOT17-04	1	29.45	33.45	38.04	41.90	2.19	52.29	1.95	3.90	0.51
oc-sort	MOT17-04	2	29.48	33.42	37.65	40.84	1.43	51.81	1.94	3.88	0.51
polytrack-x	MOT17-04	1	30.29	32.60	36.22	38.38	0.86	31.33	2.02	3.93	0.49
polytrack-x	MOT17-04	2	29.52	33.28	38.13	43.49	2.38	48.10	1.94	3.90	0.49
tracktrack	MOT17-04	1	18.63	53.56	57.92	61.69	100.00	100.00	2.91	3.89	0.47
tracktrack	MOT17-04	2	18.71	53.42	57.63	60.96	100.00	100.00	2.83	3.90	0.47
bytetrack	MOT17-05	1	31.32	31.08	35.43	39.88	1.08	15.77	1.91	3.88	0.46
bytetrack	MOT17-05	2	32.08	30.75	35.21	39.77	1.08	13.74	1.86	3.91	0.46
clasp	MOT17-05	1	31.54	31.02	35.72	40.63	1.43	18.76	1.87	3.90	0.48
clasp	MOT17-05	2	31.69	31.11	35.30	40.09	1.08	14.81	1.94	3.91	0.48
clasp-lite	MOT17-05	1	32.10	30.75	34.64	36.93	0.36	12.19	1.95	3.92	0.48
clasp-lite	MOT17-05	2	31.24	31.14	36.81	43.99	2.03	19.35	2.15	3.90	0.48
oc-sort	MOT17-05	1	31.79	30.89	35.41	39.50	0.96	16.61	1.83	3.91	0.50
oc-sort	MOT17-05	2	30.00	32.76	37.37	40.35	1.31	40.26	1.88	3.92	0.50
polytrack-x	MOT17-05	1	31.74	30.86	35.21	40.85	1.19	14.93	1.89	3.90	0.48
polytrack-x	MOT17-05	2	30.90	31.65	36.62	40.47	1.19	23.18	1.90	3.90	0.48
tracktrack	MOT17-05	1	23.23	42.84	48.27	51.65	84.23	99.88	2.39	3.88	0.46
tracktrack	MOT17-05	2	23.21	42.84	48.84	52.80	82.56	100.00	2.40	3.88	0.46
bytetrack	MOT17-09	1	30.20	32.69	36.23	38.13	0.19	34.86	1.92	3.90	0.46
bytetrack	MOT17-09	2	30.00	32.72	37.25	39.50	0.95	37.71	1.89	3.89	0.46
clasp	MOT17-09	1	29.13	33.89	38.21	42.95	1.71	63.43	1.96	3.89	0.49
clasp	MOT17-09	2	29.55	33.35	37.95	43.64	1.71	50.67	2.05	3.89	0.49
clasp-lite	MOT17-09	1	29.50	33.45	37.30	41.53	1.52	53.90	1.97	3.88	0.48
clasp-lite	MOT17-09	2	29.15	33.62	38.83	44.68	3.24	56.57	2.05	3.85	0.48
oc-sort	MOT17-09	1	29.97	32.80	37.33	41.57	1.52	38.67	1.91	3.89	0.51
oc-sort	MOT17-09	2	29.79	33.09	36.90	39.23	0.38	43.81	1.92	3.91	0.50
polytrack-x	MOT17-09	1	29.85	33.05	37.27	40.29	1.33	44.19	1.84	3.89	0.49
polytrack-x	MOT17-09	2	29.82	33.06	37.24	39.49	0.95	44.95	1.84	3.91	0.49
tracktrack	MOT17-09	1	18.82	53.27	57.92	59.63	100.00	100.00	2.85	3.91	0.47
tracktrack	MOT17-09	2	18.59	53.75	57.97	60.35	100.00	100.00	2.83	3.89	0.47
bytetrack	MOT17-10	1	28.97	33.80	40.10	47.23	5.20	56.88	1.95	3.86	0.46
bytetrack	MOT17-10	2	30.44	32.36	36.66	40.23	1.07	31.19	1.89	3.89	0.46
clasp	MOT17-10	1	29.13	33.39	41.01	49.65	5.81	51.38	2.03	3.86	0.49
clasp	MOT17-10	2	30.16	32.62	36.82	41.93	1.38	35.02	1.85	3.90	0.49
clasp-lite	MOT17-10	1	28.87	33.98	39.42	42.92	3.98	64.22	1.89	3.86	0.49
clasp-lite	MOT17-10	2	30.61	32.19	35.98	40.02	1.07	26.91	1.90	3.90	0.49
oc-sort	MOT17-10	1	29.10	33.55	40.05	48.85	5.20	53.98	1.90	3.85	0.51
oc-sort	MOT17-10	2	30.52	32.21	36.33	39.62	0.76	27.37	1.87	3.91	0.50
polytrack-x	MOT17-10	1	27.75	34.96	41.67	57.22	7.34	82.72	1.97	3.82	0.49
polytrack-x	MOT17-10	2	30.51	32.35	36.16	41.36	1.22	28.59	1.90	3.90	0.49
tracktrack	MOT17-10	1	18.21	54.40	60.56	73.66	100.00	100.00	2.81	3.85	0.47
tracktrack	MOT17-10	2	18.63	53.68	58.09	62.03	100.00	100.00	2.93	3.89	0.47
bytetrack	MOT17-11	1	30.60	32.17	36.04	39.58	0.78	26.56	1.89	3.90	0.46
bytetrack	MOT17-11	2	30.23	32.55	36.83	41.52	1.89	33.89	1.84	3.89	0.46
clasp	MOT17-11	1	28.60	34.58	38.53	41.22	2.11	79.44	1.92	3.86	0.49
clasp	MOT17-11	2	29.76	33.20	37.26	41.02	1.22	47.44	1.89	3.91	0.49
clasp-lite	MOT17-11	1	29.85	33.01	37.38	40.67	1.33	43.89	1.88	3.88	0.49
clasp-lite	MOT17-11	2	29.92	32.96	37.03	39.96	0.89	42.78	2.02	3.89	0.49
oc-sort	MOT17-11	1	30.65	32.13	36.13	39.66	0.89	26.22	1.99	3.90	0.50
oc-sort	MOT17-11	2	30.43	32.25	37.04	40.93	1.67	30.33	1.92	3.89	0.50
polytrack-x	MOT17-11	1	30.61	32.15	36.16	40.45	1.22	27.56	1.94	3.90	0.49
polytrack-x	MOT17-11	2	30.42	32.45	36.21	38.64	0.78	32.56	1.85	3.88	0.49
tracktrack	MOT17-11	1	18.60	53.85	58.14	61.11	100.00	100.00	2.89	3.90	0.47
tracktrack	MOT17-11	2	18.56	53.81	58.59	64.06	100.00	100.00	2.91	3.89	0.47

tracker	sequence	repeat	fps	p50	p95	p99	miss40	miss33	J_frame	cores	GB
bytetrack	MOT17-13	1	29.74	33.11	37.34	41.09	1.47	44.53	1.94	3.89	0.46
bytetrack	MOT17-13	2	29.60	33.22	38.14	40.43	1.73	47.73	1.99	3.88	0.46
clasp	MOT17-13	1	30.01	32.87	37.22	40.64	1.47	37.47	1.91	3.90	0.49
clasp	MOT17-13	2	30.09	32.88	36.61	40.37	1.73	40.13	1.84	3.89	0.48
clasp-lite	MOT17-13	1	30.18	32.66	36.71	40.89	1.73	35.73	1.85	3.88	0.48
clasp-lite	MOT17-13	2	30.03	32.77	36.77	40.06	1.07	38.80	1.97	3.89	0.48
oc-sort	MOT17-13	1	30.24	32.65	36.41	40.05	1.07	34.27	1.93	3.90	0.50
oc-sort	MOT17-13	2	30.54	32.23	36.28	39.84	1.07	26.80	1.85	3.92	0.50
polytrack-x	MOT17-13	1	30.17	32.62	36.68	41.68	1.47	35.47	1.88	3.88	0.49
polytrack-x	MOT17-13	2	30.41	32.43	36.63	38.43	0.80	30.80	1.85	3.90	0.49
tracktrack	MOT17-13	1	18.38	54.45	59.24	63.35	100.00	100.00	2.91	3.88	0.47
tracktrack	MOT17-13	2	18.48	54.17	58.86	61.58	100.00	100.00	2.89	3.90	0.47

11 Scheduling the detector

Scripts: `detsched.py`, `run_detsched_screen.py` (replay), `run_detsched_live.py` (live, RAPL), `run_detsched_cropbench.py`, `analyze_detsched_heldout.py`; full record in `48_detsched/EXPERIMENT_LOG.md`. Panel = 8 design sequences (MOT17-10/02/13, MOT20-01, dancetrack0001/0008/0012/0020).

Table 11 Measured cost of one YOLO11m call on a canvas of area a network pixels (RAPL package, gross; 3 rounds × 40 calls per shape): $E = a_J + b_J\, a$

quantity	value
a_J	0.5662
b_J_per_px	3.471e-05
a_ms	9.479
b_ms_per_px	0.0005039
m_full_J	8.817
n_full_J	1.643
m_full_ms	133.6
n_full_ms	26.84
idle_W	16.95
predicted_full_from_fit_J	9.097

Table 12: Replay rounds on the panel (energy from the per-call cost model; differences of R4 use the campaign cost of YOLO11m). R11 onwards use the interior membership rule and the mosaic

round	policy	HOTA	IDF1	MOTA	J_per_frame	energy_saving
R4	only_n	31.765	35.157	45.018	1.913	0.799
R4	trig_orph_mg50_k0	31.500	35.251	45.348	3.147	0.669
R4	trig_orph+unc_mg25_k0_u40	33.801	38.345	52.254	4.607	0.516
R4	trig_unc_mg50_k0	35.174	39.413	53.205	5.200	0.454
R4	trig_orph+unc_mg50_k0_lb10	35.177	39.486	53.452	5.408	0.432
R4	trig_orph+unc_mg50_k0	35.311	40.186	53.463	5.696	0.402
R4	periodic2_n	33.437	37.241	50.602	5.721	0.399
R4	trig_orph+unc+ovl_mg50_k0	35.939	40.251	53.985	6.509	0.316
R4	only_m	36.722	40.599	54.925	9.523	0.000
R8	voi_l160_r10_mg50	35.113	39.565	51.848	4.311	0.547
R8	voi_l80_r10_mg50	35.912	40.532	53.048	4.741	0.502
R8	voi_l40_r10_mg50	35.566	39.288	53.968	5.116	0.463
R8	voi_l20_r10_mg50	36.573	40.856	54.443	5.465	0.426
R8	vs_l40_k30_g6x4	36.089	40.586	54.123	5.475	0.425
R8	trig_orph+unc_mg50_k0	36.087	40.663	54.383	5.668	0.405
R8	trig_orph+unc+ovl_mg50_k0	36.211	40.123	54.679	6.502	0.317
R8	only_m	36.722	40.599	54.925	9.523	0.000
R11	only_n	31.765	35.157	45.018	1.643	0.814
R11	voi_l80_r10_mg50_noorph	34.549	39.271	52.531	4.716	0.465
R11	voi_l80_r10_mg50_noorph_s1	35.651	40.249	53.279	4.861	0.449
R11	voi_l40_r10_mg50_noorph	35.303	40.028	53.459	5.067	0.425
R11	voi_l40_r10_mg50_noorph_s1	34.143	37.998	53.573	5.120	0.419
R11	voi_l20_r10_mg50_noorph_s2	35.065	39.191	53.940	5.388	0.389
R11	voi_l20_r10_mg50_noorph	35.300	39.826	53.999	5.418	0.385
R11	voi_l20_r10_mg50_noorph_s1	35.213	39.413	54.072	5.427	0.384
R11	voi_l20_r10_mg50_s1	35.990	40.444	54.164	5.623	0.362
R11	voi_l20_r10_mg50_s2	36.569	41.464	54.231	5.647	0.360
R11	voi_l20_r10_mg50	36.773	41.898	54.213	5.666	0.357
R11	voi_l10_r10_mg50_noorph	35.922	40.051	54.162	5.680	0.356
R11	voi_l10_r10_mg50_noorph_s1	35.543	39.836	54.265	5.680	0.356
R11	only_m	36.722	40.599	54.925	8.817	0.000
R16	voi_l40_r10_mg15	35.146	39.503	53.941	4.563	0.482
R16	voi_l20_r10_mg25_hm48	36.662	41.245	54.025	4.638	0.474

round	policy	HOTA	IDF1	MOTA	J_per_frame	energy_saving
R16	voi_l20_r10_mg25_hm48_s1	36.037	40.856	53.917	4.644	0.473
R16	voi_l40_r10_mg15_s1	35.715	40.162	53.982	4.671	0.470
R16	voi_l40_r10_mg25_s2	35.971	40.374	53.808	4.766	0.459
R16	voi_l40_r10_mg25_s1	35.963	40.478	53.815	4.794	0.456
R16	voi_l40_r10_mg25	35.221	39.356	53.740	4.808	0.455
R16	voi_l20_r10_mg15_s1	35.963	40.349	54.079	4.841	0.451
R16	voi_l20_r10_mg15_s2	35.954	40.567	54.128	4.880	0.447
R16	voi_l20_r10_mg15	35.939	40.229	54.116	4.885	0.446
R16	voi_l20_r10_mg25_s2	37.020	42.367	54.067	5.033	0.429
R16	voi_l20_r10_mg10_s1	36.380	40.875	54.097	5.036	0.429
R16	voi_l20_r10_mg10	36.670	41.064	54.131	5.097	0.422
R16	only_m	36.722	40.599	54.925	8.817	0.000

Table 13 Live panel (real YOLO11n on every frame, real YOLO11m mosaic, RAPL package gross): value-of-information and threshold verification against YOLO11m on every frame

tracker	HOTA	MOTA	IDF1	J	ms	area	dHOTA	dMOTA	dIDF1	saving
catdet_t10_mg25	37.927	55.592	41.428	8.165	140.661	0.542	1.205	0.666	0.830	0.106
catdet_t30_mg25	37.422	54.958	41.894	7.173	119.983	0.521	0.700	0.033	1.295	0.215
catdet_t60_mg25	37.094	55.028	41.021	6.926	112.996	0.517	0.372	0.103	0.422	0.242
only_m	36.722	54.925	40.599	9.133	138.021	0.000	0.000	0.000	0.000	0.000
voi_l10_r10_mg25	36.387	51.475	40.378	5.881	100.108	0.383	-0.335	-3.450	-0.220	0.356
voi_l20_r10_mg25	37.309	51.481	42.334	5.987	97.514	0.355	0.587	-3.444	1.735	0.344
voi_l40_r10_mg25	36.133	50.185	40.338	5.406	92.480	0.329	-0.589	-4.740	-0.261	0.408

Pre-registration — held-out confirmation of the frozen detector-scheduling policy

Written 2026-10-12, before any held-out run of the policy. No held-out sequence has been used to design, tune or select the policy: every screening run used the 8-sequence design panel.

The 76 development sequences were observed before, for CLASP itself. They are new data for this mechanism only, so this is a held-out confirmation and not a blind test. The blind test would be the official test servers; the author submits.

Frozen policy

`voi_l20_r10_mg25`, i.e. `detsched.VoI` with:

- $\lambda = 0.02$, $\rho = 1$, margin 0.25, $\varepsilon = 0.03$, lookback 30, seed 0;
- the interior membership rule (TOL = 4 network px);
- one YOLO11m mosaic call per frame;
- tracker = final CLASP (`clasp_final.CLASP`), unchanged.

Execution is live: `run_detsched_live.py` with real YOLO11n on every frame and real YOLO11m on the mosaic, via `detsched_infer.FastYOLO`. The reference is `only_m`, i.e. the final CLASP with YOLO11m on every frame, run through the same code path. Both run in the same process, in a seeded order per sequence, pinned to 4 P-cores, 4 threads, EcoQoS off.

Code hashes (SHA-256):

```
detsched.py             20861ec6208cde98991636f354ced1d55e334b8d5d1d2d8c8175427b04bda90b
detsched_policies.py    aad2ea12b132ecbe3238e1cd779bbcc62cbe3b9a4557efc5543df4f8164eea13
run_detsched_live.py    9f2dd5c071d56f0ace0683bd17c70bd2c4d39a2821f71708ade3685ac43fc61c
detsched_infer.py       94ed42f9c0676755b4e83c112a36c74bb7a8ac3fa9a9bc2b89a6abe024b7cb76
clasp_final.py          735bbdc54fc940f9e2f407f28352644b392badd607818f7440c8405633924599
run_detsched_screen.py  97d88ebe7fc585b6d7983d3099eaf460a286e70fadad838e82733be050cbebac
```

Units

The held-out pool has 68 sequences: 61 DanceTrack, 4 MOT17 and 3 MOT20. A cost-limited subset of 24 sequences was drawn with numpy `default_rng(20261012)` before any run. It contains every MOT17 and MOT20 held-out sequence, plus 17 DanceTrack sequences, 29,797 frames in total:

```
MOT17/train/MOT17-04-FRCNN MOT17/train/MOT17-05-FRCNN MOT17/train/MOT17-09-FRCNN MOT17/train/MOT17-11-FRCNN
MOT20/train/MOT20-02 MOT20/train/MOT20-03 MOT20/train/MOT20-05
DanceTrack/train/dancetrack0002 DanceTrack/train/dancetrack0053 DanceTrack/train/dancetrack0057 DanceTrack/train/dancetrack0062
DanceTrack/train/dancetrack0069 DanceTrack/train/dancetrack0080 DanceTrack/train/dancetrack0096 DanceTrack/val/dancetrack0010
DanceTrack/val/dancetrack0014 DanceTrack/val/dancetrack0019 DanceTrack/val/dancetrack0026 DanceTrack/val/dancetrack0034
DanceTrack/val/dancetrack0041 DanceTrack/val/dancetrack0063 DanceTrack/val/dancetrack0065 DanceTrack/val/dancetrack0094
DanceTrack/val/dancetrack0097
```

Decision rule (unit = sequence; paired differences policy − only_m; 95% bootstrap CI, 10,000 resamples) **Primary — all three must hold for "confirmed":**

- **E:** the measured RAPL energy saving per frame, frame-weighted, is ≥ 30%, and the lower bound of the CI over sequences is ≥ 25%.
- **H:** mean ΔHOTA has a CI lower bound > −1.0. This is the non-inferiority margin. It is justified by the noise floor (R13): dropping 0.5% of m detections moves the 8-sequence panel mean HOTA by −0.08 to −0.72.
- **I:** mean ΔIDF1 has a CI lower bound > −1.0.

Reported without a decision role:

- ΔMOTA, ΔDetA, ΔAssA, FP, FN and IDSW;
- per-dataset results;
- latency per frame (mean and p95 are not recorded per frame here; the mean is reported);
- the share of frames with a crop and the mosaic area.

The live panel (L3) showed ΔMOTA −3.4, so a MOTA loss is expected and will be reported as a limitation.
Context baselines on the same 24 sequences, replay (exact for frame-level policies):

- only_n (YOLO11n everywhere);
- periodic2_n (YOLO11m on every second frame);
- only_s where the s cache exists (17 of 24).

No retries. If the rule fails, the result is reported as such, and any further change is a new pre-registered experiment on new data.

Table 14 Held-out confirmation (24 sequences, live): paired differences policy − YOLO11m with 95% bootstrap CI; frame-weighted energy saving -2.3%; verdict: NOT confirmed

metric	mean	ci_lo	ci_hi
HOTA	-0.329	-3.150	2.228
IDF1	0.706	-3.064	4.399
MOTA	0.333	-2.006	3.169
DetA	-0.611	-2.587	1.722
AssA	-0.753	-4.014	1.967
FP	233.542	-38.458	603.854
FN	-6309.333	-15091.946	-68.156
IDSW	55.875	-0.333	129.422
saving_seq	0.235	-0.016	0.435

Table 15: Held-out confirmation per sequence (difference policy − YOLO11m; saving = 1 − energy ratio)

dataset	sequence	HOTA	IDF1	MOTA	saving
DanceTrack	dancetrack0002	7.63	6.47	0.17	0.53
DanceTrack	dancetrack0010	-21.85	-25.75	-0.81	0.70
DanceTrack	dancetrack0014	-1.93	1.16	-1.29	0.54
DanceTrack	dancetrack0019	-3.24	-5.33	-2.70	0.52
DanceTrack	dancetrack0026	-0.11	-1.39	-0.80	-0.01
DanceTrack	dancetrack0034	-2.65	-3.37	-3.03	0.28
DanceTrack	dancetrack0041	-0.90	-1.18	-3.48	0.40
DanceTrack	dancetrack0053	1.00	3.47	-0.82	0.49
DanceTrack	dancetrack0057	-3.35	-0.36	-8.49	0.52
DanceTrack	dancetrack0062	-1.00	-2.60	-6.44	0.49
DanceTrack	dancetrack0063	2.93	1.97	-1.44	0.18
DanceTrack	dancetrack0065	-13.62	-16.63	-3.97	0.45
DanceTrack	dancetrack0069	3.15	6.10	-2.09	0.67
DanceTrack	dancetrack0080	5.84	7.27	-2.23	0.42
DanceTrack	dancetrack0094	2.40	4.73	-1.63	0.30
DanceTrack	dancetrack0096	-3.99	-2.92	-4.26	0.49
DanceTrack	dancetrack0097	0.26	6.75	-1.16	0.70
MOT17	MOT17-04-FRCNN	5.14	9.20	13.07	0.05
MOT17	MOT17-05-FRCNN	-2.04	-3.06	-0.10	0.25
MOT17	MOT17-09-FRCNN	-1.34	-3.44	-0.38	0.41
MOT17	MOT17-11-FRCNN	-2.18	-3.25	2.49	0.45
MOT20	MOT20-02	2.39	3.60	4.67	-0.06
MOT20	MOT20-03	13.22	24.68	23.05	-1.74
MOT20	MOT20-05	6.37	10.82	9.66	-1.39

12 Per-frame tracking latency of the association-only workload

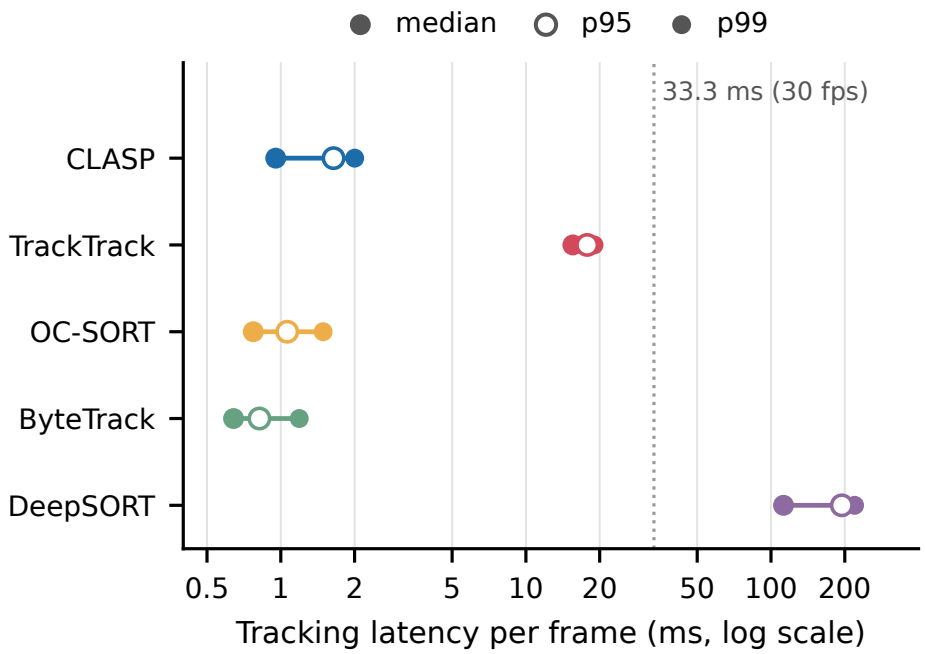


Fig. S2 Per-frame tracking latency in W1 (medians over 152 runs per tracker of the per-run median, 95th and 99th percentile) against the 30 fps deadline