

**INTERNATIONAL ORGANISATION FOR STANDARDISATION  
ORGANISATION INTERNATIONALE DE NORMALISATION  
ISO/IEC JTC1/SC29/WG11  
CODING OF MOVING PICTURES AND AUDIO**

**Verification Report of Core Experiment on Fast Block-Matching Motion Estimation using Advanced Diamond Zonal Search with Embedded Radar**

ISO/IEC JTC1/SC29/WG11  
MPEG99/M5116  
October 1999

From: Gabriel Tsechpenakis, Yannis Avtithis and Stefanos Kollias  
Image, Video and Multimedia Systems Laboratory,  
Computer Science Division,  
Department of Electrical and Computer Engineering,  
National Technical University of Athens,  
Athens GR-15773, GREECE  
[gtsech@image.ntua.gr](mailto:gtsech@image.ntua.gr), [iavr@image.ntua.gr](mailto:iavr@image.ntua.gr) and [stefanos@cs.ntua.gr](mailto:stefanos@cs.ntua.gr)

**Abstract**

Motion Estimation (ME) is an important part of the MPEG-4 encoder, since it could significantly affect the output quality of the encoded sequence. Unfortunately this feature requires a significant part of the encoding time especially when using the straightforward Full Search (FS) Algorithm. The Diamond Search (DS) was recently accepted as a fast motion estimation algorithm for the MPEG4 VM. In this report we verify the results extracted by the Advanced Diamond Zonal Search with Embedded Radar algorithm (ADZS-ER), proposed by Alexis M. Tourapis, Oscar C. Au, Ming L. Liou, and Guobin Shen (ISO/IEC JTC1/SC29/WG11, MPEG99/M4980). The experiments were carried out under the same conditions and the results verify the superiority of the proposed algorithm towards the DS algorithm, especially in the high bit rate cases, regarding the speed (in terms of number of checking points and total encoding time) and the quality (in terms of PSNR) of the output sequence.

<i>Table 1: PSNR</i>								
Sequence	size	BR	SA	psnrY	psnrU	psnrV	bits	
Container	qcif	10	16	FS	29.805737	37.538784	36.602982	98792
				DS	29.757656	37.427361	36.579460	99752
				ADZS	29.778538	37.490536	36.669956	98960
			32	FS	29.716650	37.545334	36.565186	98912
				DS	29.735569	37.483986	36.691990	98912
				ADZS	29.785273	37.573971	36.627178	99136
Hall Monitor	qcif	10	16	FS	30.350121	36.382256	39.565144	99448
				DS	30.321072	36.346043	39.550953	99288
				ADZS	30.282875	36.429379	39.564922	99616
			32	FS	30.294138	36.236675	39.489223	99360
				DS	30.290556	36.357487	39.572369	99472
				ADZS	30.329134	36.377499	39.519363	99200
Mom & Daughter	qcif	24	16	FS	34.798161	40.233021	41.015671	238936
				DS	34.775394	40.416065	41.072964	239048
				ADZS	34.714867	40.196548	41.022339	239000
			32	FS	34.809479	40.280228	40.978287	239088
				DS	34.732594	40.232933	40.964943	239008
				ADZS	34.671452	40.254341	40.896130	239048
Silence	qcif	24	16	FS	30.818794	35.206730	36.604324	238560
				DS	30.921614	35.292229	36.729095	239024
				ADZS	30.950495	35.382153	36.776226	239032
			32	FS	30.901735	35.288910	36.632221	238992
				DS	30.934324	35.342964	36.759140	239752
				ADZS	30.845901	35.252029	36.732262	239808
Coast-guard	qcif	48	16	FS	28.883966	40.143433	42.069382	476960
				DS	28.731472	40.066330	42.140507	477808
				ADZS	28.825176	40.277000	41.919968	477696
			32	FS	28.895437	40.024273	41.877453	476824
				DS	28.707914	40.172970	42.155396	477600
				ADZS	28.812954	40.175613	41.957821	477640

News	cif	48	16	FS	31.844421	35.720787	37.310387	477576
				DS	31.817617	36.115704	37.463932	475184
				ADZS	31.773460	36.310589	37.632313	475216
			32	FS	31.896461	35.788334	37.347694	477640
				DS	31.921516	36.087994	37.498791	477656
				ADZS	31.734392	36.176929	37.687733	472568
News	cif	112	16	FS	34.054253	38.044567	38.933163	1118416
				DS	33.857838	37.991901	38.994923	1119736
				ADZS	34.022484	38.102245	38.970528	1119584
			32	FS	34.033779	37.928833	38.848392	1115936
				DS	33.989925	38.074387	38.987732	1119336
				ADZS	33.851685	38.020950	38.920563	1115144
Coast-guard	cif	112	16	FS	27.032761	38.867691	41.650402	1112576
				DS	26.442659	38.790806	41.463219	1113232
				ADZS	27.070173	39.103878	41.645458	1112400
			32	FS	27.055731	38.639767	40.994152	1112656
				DS	26.467796	38.770504	41.591015	1117360
				ADZS	27.060457	38.987534	41.601730	1115176
Foreman	cif	112	16	FS	30.039257	36.776501	37.529190	1114704
				DS	29.576139	36.562378	37.432316	1114784
				ADZS	29.688862	36.966366	37.920662	1114856
			32	FS	30.365582	36.878025	37.564667	1114560
				DS	29.632263	36.569279	37.371181	1114768
				ADZS	29.672859	36.950672	37.852676	1114688
Foreman	cif	512	16	FS	34.511021	40.250534	41.468937	5121912
				DS	34.071220	39.956337	41.167904	5121848
				ADZS	34.406040	40.191551	41.453590	5121776
			32	FS	34.836208	40.556030	41.748634	5121960
				DS	34.093792	39.973999	41.169422	5121920
				ADZS	34.401024	40.195934	41.456207	5121784
			48	FS	34.875107	40.619396	41.789616	5121784
				DS	34.100174	39.984142	41.179726	5121856
				ADZS	34.380787	40.184189	41.440544	5121968

Foreman	cif	1024	16	FS	35.471836	41.047123	42.355381	10240032
				DS	34.974030	40.643028	41.946129	10240456
				ADZS	35.237576	40.827351	42.179409	10240552
			32	FS	35.531193	41.125603	42.427731	10240312
				DS	34.967976	40.644596	41.942173	10240448
				ADZS	35.239925	40.837849	42.170094	10240528
			48	FS	35.505745	41.108875	42.403454	10240160
				DS	34.961514	40.634403	41.935688	10240040
				ADZS	35.217922	40.824051	42.157269	10240640
Table	sif	1024	16	FS	34.984882	41.891087	41.011276	10240968
				DS	34.923603	41.812134	40.925529	10241200
				ADZS	34.947826	41.834137	40.959728	10240880
			32	FS	35.002342	41.905952	41.021515	10241208
				DS	34.903679	41.808197	40.919998	10241192
				ADZS	34.907146	41.819412	40.945065	10241080
			48	FS	34.972519	41.884266	41.005295	10241168
				DS	34.920982	41.820980	40.920334	10241144
				ADZS	34.911579	41.818222	40.939480	10241112
Table	sif	2048	16	FS	38.384533	43.656071	42.892620	20518400
				DS	38.304630	43.581715	42.810715	20518312
				ADZS	38.316128	43.607647	42.829174	20518128
			32	FS	38.383499	43.653259	42.890606	20518112
				DS	38.303699	43.582088	42.808754	20518104
				ADZS	38.311268	43.604183	42.824657	20518464
			48	FS	38.376457	43.653210	42.887547	20518352
				DS	38.298172	43.578472	42.805908	20518208
				ADZS	38.306274	43.603069	42.821121	20518304

- BR = bit rate, SA = search area
- psnrY = peak signal-to-noise ratio of the Y component. Similar definition for psnrU and psnrV.

<i>Table 2: time</i>							
Sequence	size	BR	SA		User	system	total
Container	qcif	10	16	FS	62.570	0.360	62.930
				DS	19.640	0.340	19.980
				ADZS	19.140	0.380	19.520
			32	FS	154.380	0.400	154.780
				DS	19.580	0.370	19.950
				ADZS	19.220	0.340	19.560
Hall Monitor	qcif	10	16	FS	53.010	0.350	53.360
				DS	19.570	0.240	19.810
				ADZS	19.060	0.340	19.400
			32	FS	124.580	0.450	125.030
				DS	19.480	0.360	19.840
				ADZS	19.070	0.310	19.380
Mom & Daughter	qcif	24	16	FS	72.250	1.050	73.300
				DS	26.360	0.830	27.190
				ADZS	25.920	0.710	26.630
			32	FS	171.140	0.830	171.970
				DS	26.490	0.770	27.260
				ADZS	25.720	0.920	26.640
Silence	qcif	24	16	FS	78.640	0.660	79.300
				DS	26.610	0.650	27.260
				ADZS	26.210	0.590	26.800
			32	FS	185.070	0.730	185.800
				DS	26.780	0.540	27.320
				ADZS	26.230	0.620	26.850
Coast-guard	qcif	48	16	FS	92.270	0.230	92.500
				DS	27.010	0.240	27.250
				ADZS	26.500	0.290	26.790
			32	FS	239.080	0.240	239.320
				DS	26.950	0.350	27.300

				ADZS	26.630	0.220	26.850
News	cif	48	16	FS	242.730	1.370	244.100
				DS	80.370	1.070	81.440
				ADZS	78.050	1.280	79.330
			32	FS	608.290	1.440	609.730
				DS	80.530	1.200	81.730
				ADZS	77.960	1.450	79.410
News	cif	112	16	FS	467.780	2.560	470.340
				DS	160.590	2.120	162.710
				ADZS	156.260	2.140	158.400
			32	FS	1164.550	2.420	1166.970
				DS	160.520	2.120	162.640
				ADZS	156.000	1.870	157.870
Coast-guard	cif	112	16	FS	398.610	2.950	401.560
				DS	112.640	2.760	115.400
				ADZS	111.480	3.140	114.620
			32	FS	1095.380	2.860	1098.240
				DS	112.580	3.020	115.600
				ADZS	111.400	3.240	114.640
Foreman	cif	112	16	FS	331.250	2.640	333.890
				DS	111.330	2.910	114.240
				ADZS	108.010	2.830	110.840
			32	FS	808.940	2.600	811.540
				DS	112.490	2.350	114.840
				ADZS	108.350	2.460	110.810
Foreman	cif	512	16	FS	456.430	1.140	457.570
				DS	168.630	0.900	169.530
				ADZS	162.870	0.750	163.620
			32	FS	1081.920	0.920	1082.840
				DS	169.070	0.880	169.950
				ADZS	162.820	0.750	163.570
			48	FS	1923.120	0.960	1924.080
				DS	169.250	0.930	170.180
				ADZS	162.800	0.740	163.540

Foreman	cif	1024	16	FS	884.710	1.840	886.550
				DS	335.370	1.870	337.240
				ADZS	324.260	1.800	326.060
			32	FS	2088.830	1.860	2090.690
				DS	335.500	1.930	337.430
				ADZS	324.210	1.770	325.980
			48	FS	3713.190	1.850	3715.040
				DS	335.640	1.900	337.540
				ADZS	324.510	1.730	326.240
Table	sif	1024	16	FS	819.530	1.720	821.250
				DS	273.610	1.750	275.360
				ADZS	266.960	1.600	268.560
			32	FS	2092.240	1.660	2093.900
				DS	273.790	1.740	275.530
				ADZS	267.220	1.570	268.790
			48	FS	3846.400	1.590	3847.990
				DS	273.800	1.620	275.420
				ADZS	266.960	1.470	268.430
Table	sif	2048	16	FS	814.230	1.480	815.710
				DS	283.270	1.430	284.700
				ADZS	276.540	1.440	277.980
			32	FS	2057.440	1.720	2059.160
				DS	283.380	1.470	284.850
				ADZS	276.630	1.400	278.030
			48	FS	3766.170	1.550	3767.720
				DS	283.170	1.550	284.720
				ADZS	276.390	1.520	277.910

- BR = bit rate, SA = search area
- Timing is performed on a Sun Ultra 10 machine, without profiling and counter.

*Table 3: Speed-up*

sequence	size	BR	SA	Checking points	line-SAD	FS/SA=16	speed-up	
Container	qcif	10	16	FS	7501824	68302357	7501824	1.0000
				DS	96969	980438	7501824	77.3631
				ADZS	42840	432575	7501824	175.112
			32	FS	27142090	216387987	7501824	0.2764
				DS	97030	983232	7501824	77.3145
				ADZS	43148	433649	7501824	173.8626
Hall Monitor	qcif	10	16	FS	7501824	54002688	7501824	1.0000
				DS	96927	863941	7501824	77.3966
				ADZS	42137	419900	7501824	178.0341
			32	FS	27142090	169757780	7501824	0.2764
				DS	97209	872155	7501824	77.1721
				ADZS	40794	408892	7501824	183.8953
Mom & Daughter	qcif	24	16	FS	10036224	73566955	10036224	1.0000
				DS	135676	1281619	10036224	73.9720
				ADZS	46766	596818	10036224	214.6051
			32	FS	36311715	232469783	10036224	0.2764
				DS	47312	602562	10036224	212.1285
				ADZS	47312	602562	10036224	212.1285
Silence	qcif	24	16	FS	10036224	83127826	10036224	1.0000
				DS	146141	1563459	10036224	68.6749
				ADZS	97658	1203564	10036224	102.7691
			32	FS	36311715	254215255	10036224	0.2764
				DS	146243	1564111	10036224	68.6270
				ADZS	98459	1208703	10036224	101.9330
Coast-guard	qcif	48	16	FS	10036224	99997375	10036224	1.0000
				DS	171767	1982863	10036224	58.4293
				ADZS	142307	1567522	10036224	70.5252
			32	FS	36311715	324712738	10036224	0.2764
				DS	171556	1984128	10036224	58.5012
				ADZS	142898	1573791	10036224	70.2335



News	cif	48	16	FS	30007296	257914930	30007296	1.0000
				DS	441188	4776688	30007296	68.0148
				ADZS	217693	2649065	30007296	137.8423
			32	FS	114227658	843222392	30007296	0.2627
				DS	443590	4784255	30007296	67.6465
				ADZS	219693	2673670	30007296	136.5874
News	cif	112	16	FS	60420096	485966112	60420096	1.0000
				DS	832799	7859307	60420096	72.5506
				ADZS	292760	3506010	60420096	206.3810
			32	FS	229998933	1601397125	60420096	0.2627
				DS	835773	7924857	60420096	72.2925
				ADZS	293583	3508813	60420096	205.8024
Coast-guard	cif	112	16	FS	40144896	436958221	40144896	1.0000
				DS	811384	10979746	40144896	49.4771
				ADZS	837308	10636965	40144896	47.9452
			32	FS	152818083	1494261189	40144896	0.2627
				DS	818603	11072882	40144896	49.0407
				ADZS	845089	10749119	40144896	47.5037
Foreman	cif	112	16	FS	40144896	360143013	40144896	1.0000
				DS	931373	12843271	40144896	43.1029
				ADZS	745632	10048007	40144896	53.8401
			32	FS	152818083	1130148547	40144896	0.2627
				DS	968480	13396977	40144896	41.4514
				ADZS	749617	10097977	40144896	53.5539
Foreman	cif	512	16	FS	56770560	466055393	56770560	1.0000
				DS	1207842	15329481	56770560	47.0016
				ADZS	730942	9488139	56770560	77.6677
			32	FS	216106380	1469593841	56770560	0.2627
				DS	1248552	15932054	56770560	45.4691
				ADZS	731238	9479108	56770560	77.6362
			48	FS	461637680	2147483647	56770560	0.1230
				DS	1251236	15973680	56770560	45.3716
				ADZS	730984	9479079	56770560	77.6632

Foreman	cif	1024	16	FS	113541120	885956449	113541120	1.0000
				DS	2061548	24116123	113541120	55.0757
				ADZS	940068	11577650	113541120	120.7797
			32	FS	432212760	2147483647	113541120	0.2627
				DS	2082887	24426353	113541120	54.5114
				ADZS	941314	11580189	113541120	120.6198
			48	FS	923275360	2147483647	113541120	0.1230
				DS	2084544	24461382	113541120	54.4681
				ADZS	940035	11567075	113541120	120.7839
Table	sif	1024	16	FS	94617600	841202773	94617600	1.0000
				DS	1383397	12729904	94617600	68.3951
				ADZS	541962	6059421	94617600	174.5835
			32	FS	358185240	2147483647	94617600	0.2642
				DS	1386257	12787826	94617600	68.2540
				ADZS	544757	6085037	94617600	173.6877
			48	FS	760543840	2147483647	94617600	0.1244
				DS	1387092	12783285	94617600	68.2129
				ADZS	545397	6090534	94617600	173.4839
Table	sif	2048	16	FS	94617600	819411027	94617600	1.0000
				DS	1388530	12133398	94617600	68.1423
				ADZS	487339	5657198	94617600	194.1515
			32	FS	358185240	2147483647	94617600	0.2642
				DS	1391300	12176044	94617600	68.0066
				ADZS	486823	5654401	94617600	194.3573
			48	FS	760543840	2147483647	94617600	0.1244
				DS	1391824	12186672	94617600	67.9810
				ADZS	488075	5667315	94617600	193.8587

- BR=bit rate, SA=search area
- checking points = total number of checking points examined.
- line-SAD = total per line calculation of the SAD.
- The third column refers to the FS points using SA = 16.
- “speed-up” = speed up versus FS using SA = 16.
- Timing is performed on a Sun Ultra 10 machine, without profiling and counter.