Energy Consumption Optimization of Rendering in Blender Cycles on ×86 Architectures

IT4Innovations national supercomputing center

Milan Jaros, Ondrej Vysocky, Petr Strakos, Lubomir Riha

milan.jaros@vsb.cz, ondrej.vysocky@vsb.cz, petr.strakos@vsb.cz, lubomir.riha@vsb.cz

READEX Runtime Exploitation of Application Dynamism for Energy-efficient eXascale computing

Extension of Blender Cycles Renderer

We have extended Cycles [1, 2] engine in form of Blender's plug-in to support remote utilization of HPC (Hight Performance Computing) resources and to allow optimization of the energy consumption of the rendering task.

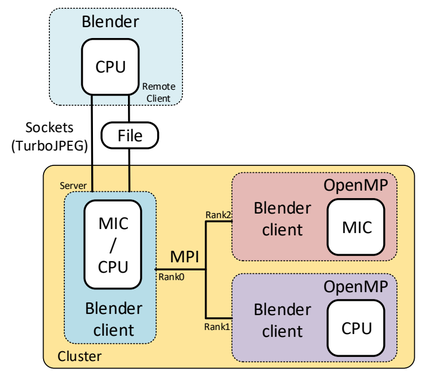

Figure 1: Concept of client and server utilizing one compute node of a cluster.

Energy measurements

In order to reduce energy consumption of a scene rendering we have used MERIC library [3] developed at IT4Innovations for HPC application resources consumption evaluation, that can also tune selected hardware parameters during the application runtime. The library allows us to do Dynamic Voltage and Core Frequency Scaling (CF) and Uncore Frequency Scaling (UnCF - Uncore frequency refers to frequency of subsystems in the physical processor package that are shared by multiple processor cores. E.g., L3 cache or on-chip ring interconnect), and control the separate parts of the chip more effectively in comparison to automated power capping.
The energy measurement of the whole node is defined by the equation

$$E = energy_{cpu} + baseline * time, \quad (1)$$

where energy consumed by CPUs is measured from Intel Running Average Power Limit (RAPL) counters and the power baseline is defined from data provided by Intelligent Platform Management Interface (IPMI). The value from IPMI is compared with the power baseline from High Definition Energy Efficiency Monitoring (HDEEM, [4]) in the Tab. 1.

HSW-freq [GHz]	1.4	1.6	1.8	2.0	2.2	2.4	turbo
HDEEM baseline [W]	65	66	68	68	69	71	73
IPMI baseline [W]						70	

KNL-freq [GHz]	1.3
HDEEM baseline [W]	-
IPMI baseline [W]	75

Table 1: The measured power baseline for Haswell and KNL by IPMI and HDEEM.

Test scenes

Figure 2: Classroom by Christophe Seux, The Daily Dweebs by Blender Foundation, Fishy Cat by Manu Jarvinen and Pabellon Barcelona by Claudio Andres (from left to righ).

Scene	Frame	Verts	Faces	Tris	Objects	Lamps	Mem	Resolution	Samples
Classroom	1	127812	126231	242474	301	4	797.11M	1920x1080	6
Dweebs	150	4643383	4160837	8066390	239	9	6738.78M	1920x1080	12
Fishy Cat	1	218761	326855	436998	27	2	908.02M	1002x460	3
Pabellon B.	1	22432	19910	40189	102	1	303.13M	1280x720	7

Table 2: Evaluated scenes description.

Test HW

IT4Innovations Salomon cluster

- 2× Intel Xeon E5-2680v3 (HSW AC) with Air Cooling system
- 2× Intel Xeon E5-2680v3 (HSW DLC) with Direct Liquid Cooling

TU-Dresden Taurus cluster

- Intel Xeon Phi Processor 7210 (KNL AC) with Air Cooling system

Heat maps - HSW AC

uncore [GHz] / core [GHz]	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1.2	152	151	150	149	148	148	148	147	147	147
1.4	132	130	129	129	128	128	127	127	126	126
1.6	117	115	114	113	113	112	112	111	111	111
1.8	105	103	102	101	101	100	100	99	99	99
2	96	94	93	92	91	91	90	90	90	89
2.2	88	87	85	84	84	83	83	82	82	82
2.4	82	80	79	78	77	76	76	76	75	75
2.8	72	70	69	68	67	66	66	66	65	65

Table 3: Heat-map representing Classroom rendering runtime [s] on 2× Intel Xeon E5-2680v3 with Air Cooling system. **The greener the shorter time.**

uncore [GHz] / core [GHz]	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1.2	26,176	26,179	26,304	26,535	26,771	27,112	27,511	28,102	28,605	29,219
1.4	23,392	23,377	23,422	23,609	23,788	24,111	24,457	24,898	25,380	25,920
1.6	21,349	21,319	21,276	21,404	21,552	21,853	22,110	22,478	22,913	23,392
1.8	19,983	19,926	19,918	19,981	20,045	20,334	20,644	20,952	21,363	21,756
2	19,576	19,381	19,342	19,361	19,408	19,592	19,895	20,196	20,537	20,909
2.2	18,869	18,748	18,638	18,620	18,721	18,829	19,125	19,357	19,684	20,059
2.4	18,602	18,384	18,286	18,319	18,295	18,441	18,649	18,883	19,154	19,496
2.8	18,879	18,608	18,482	18,392	18,435	18,459	18,611	18,899	19,048	19,318

Table 4: Heat-map representing Classroom rendering energy consumption [J] on 2× Intel Xeon E5-2680v3 with Air Cooling system. **The greener the lower energy consumption.**

Heat maps - HSW DLC

uncore [GHz] / core [GHz]	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1.2	152	151	150	149	148	148	148	148	147	147
1.4	132	130	129	129	128	128	127	127	127	126
1.6	117	115	114	114	113	112	112	112	111	111
1.8	105	104	103	101	101	100	100	100	99	99
2	96	94	93	92	91	91	91	90	90	90
2.2	88	87	86	84	84	83	83	82	82	82
2.4	82	80	79	78	77	77	76	76	76	75
2.8	72	70	69	68	67	67	66	66	65	65

Table 5: Heat-map representing Classroom rendering runtime [s] on 2× Intel Xeon E5-2680v3 with Direct Liquid Cooling. **The greener the shorter time.**

uncore [GHz] / core [GHz]	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1.2	22,504	22,554	22,780	22,956	23,222	23,624	24,090	24,647	25,176	25,845
1.4	20,304	20,369	20,481	20,629	20,945	21,259	21,591	22,073	22,558	23,112
1.6	18,729	18,784	18,791	18,984	19,197	19,442	19,785	20,150	20,564	21,038
1.8	17,989	17,965	17,994	18,049	18,265	18,459	18,761	19,112	19,488	19,916
2	17,701	17,644	17,590	17,651	17,761	18,001	18,248	18,545	18,926	19,271
2.2	17,332	17,233	17,222	17,213	17,339	17,518	17,752	18,010	18,357	18,697
2.4	17,197	17,076	17,001	17,040	17,121	17,254	17,444	17,691	18,012	18,289
2.8	18,149	17,952	17,825	17,795	17,831	17,949	18,079	18,220	18,451	18,699

Table 6: Heat-map representing Classroom rendering energy consumption [J] on 2× Intel Xeon E5-2680v3 with Direct Liquid Cooling. **The greener the lower energy consumption.**

Heat maps - KNL

core [GHz]	KNL
1	91
1.1	83
1.2	77
1.3	71
1.5	66

Table 7: Heat-map representing Classroom rendering runtime [s] on Intel Xeon Phi Processor 7210 with Air Cooling system. **The greener the shorter time.**

core [GHz]	KNL
1	17,956
1.1	17,242
1.2	16,876
1.3	16,765
1.5	16,681

Table 8: Heat-map representing Classroom rendering energy consumption [J] on Intel Xeon Phi Processor 7210 with Air Cooling system. **The greener the lower energy consumption.**

Comparison of Architectures

Platform	Default settings	Default HW configuration	Optimal settings	Optimal HW configuration	Energy and time savings
Classroom scene					
HSW AC	**19318 J; 65 s**	3 GHz (U); 2.8 GHz (C)	18286 J; 79 s	1.6GHz (U); 2.4 GHz (C)	E+5%; T-22%
HSW DLC	18699 J; 65 s	3 GHz (U); 2.8 GHz (C)	**17001 J; 79 s**	1.6GHz (U); 2.4 GHz (C)	E+12%; T-22%
KNL AC	16681 J; 66 s	1.5 GHz (C)	**16681 J; 66 s**	1.4 GHz (C)	E+14%; T-2%
Dweebs scene					
HSW AC	**19072 J; 64 s**	3 GHz (U); 2.8 GHz	18249 J; 78 s	1.8 GHz (U); 2.4 GHz (C)	E+4%; T-22%
HSW DLC	18541 J; 64 s	3 GHz (U); 2.8 GHz	**17093 J; 78 s**	1.8 GHz (U); 2.4 GHz (C)	E+10%; T-22%
KNL AC	15978 J; 62 s	1.5 GHz (C)	**15743 J; 66 s**	1.3 GHz (C)	E+17%; T-3%
Fishy Cat scene					
HSW AC	**18794 J; 63 s**	3 GHz (U); 2.8 GHz (C)	17755 J; 73 s	1.8 GHz (U); 2.4 GHz (C)	E+6%; T-16%
HSW DLC	18211 J; 63 s	3 GHz (U); 2.8 GHz (C)	**16672 J; 73 s**	1.8 GHz (U); 2.4 GHz (C)	E+11%; T-16%
KNL AC	15607 J; 61 s	1.5 GHz (C)	**15431 J; 65 s**	1.3 GHz (C)	E+18%; T-3%
Pabellon B. scene					
HSW AC	**17833 J; 60 s**	3 GHz (U); 2.8 GHz (C)	17220 J; 73 s	1.8 GHz (U); 2.4 GHz (C)	E+3%; T-22%
HSW DLC	17068 J; 60 s	3 GHz (U); 2.8 GHz (C)	**15732 J; 73 s**	1.8 GHz (U); 2.4 GHz (C)	E+12%; T-22%
KNL AC	16096 J; 63 s	1.5 GHz (C)	**15872 J; 67 s**	1.3 GHz (C)	E+11%; T-12%

Table 9: Runtime and energy consumption comparison of Haswell (HSW AC) and Knights Landing (KNL AC) nodes with Air Cooling system and Haswell with Direct Liquid Cooling (HSW DLC) in the default and optimal settings (U = uncore frequency, C = core frequency).
Comparing between architectures (HSW AC vs HSW DLC, HSW AC vs KNL AC), **up to 18% of energy can be saved while increasing the rendering time just by 3%** (The Fishy Cat scene).

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