

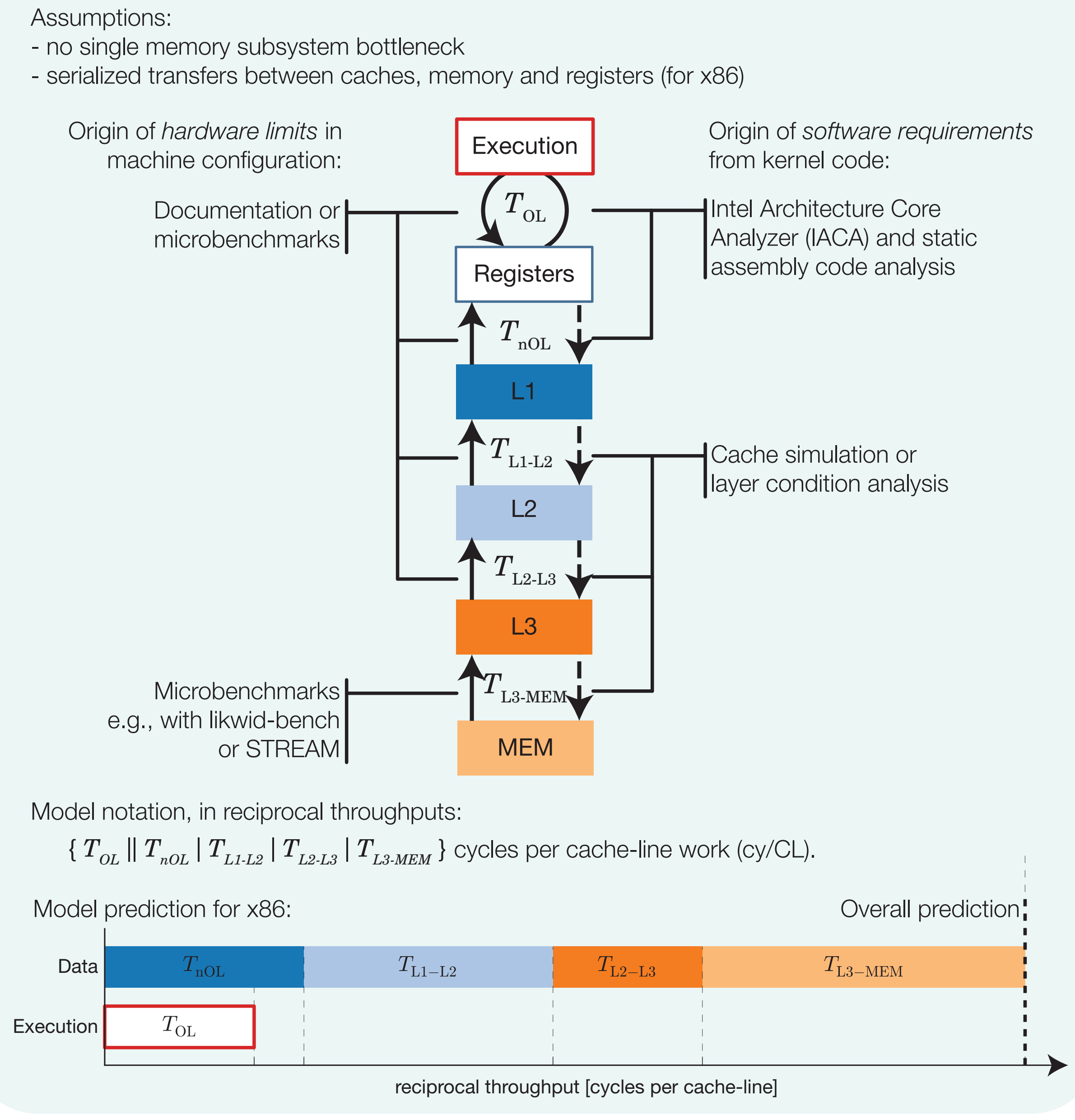
Goal

Predict performace, increase cache utilization and select the most efficient core configuration for regular algorithm implementations (streaming, stencil) on current multi-core CPUs.

Approach

1. Build Execution-Cache-Memory model
2. Predict serial performance and optimal scaling
3. Analytically select optimal spatial blocking factors

Execution-Cache-Memory (ECM) Model^[0] for x86



Future Work

- In-core simulation: Development of IACA has not been updated recently and does not support Intel Broadwell. We therefore need a replacement, which will also enable support of other architectures.
- LLVM-Polly integration: Kerncraft provides the information to guide compile-time decisions, if used in combination with a compiler. We are currently evaluating this in LLVM-Polly.
- Graph applications: Going from regular to irregular is a challenging task, which we are currently re-searching with performance modeling of graph algorithms. If feasible this will become a target of future Kerncraft releases.

References

[0] Jin Treibig and Georg Hager. Introducing a performance model for bandwidth-limited loop kernels. In *Parallel Processing and Applied Mathematics*, pages 615–624. Springer Science + Business Media, 2010. doi: 10.1007/978-3-642-14300-6_54.

[1] Julian Hammer, Georg Hager, Jan Eitzinger and Gerhard Wellein. Automatic loop kernel analysis and performance modeling with Kerncraft. In *IPDPS: 15th Proceedings of the 6th International Workshop on Performance Modeling, Benchmarking, and Simulation of High Performance Computing Systems*. doi: 10.1145/2832067.2832092.

[2] Tamas Malas, Georg Hager, Helmut Liefel, Holger Stengel, Gerhard Wellein, and David Kayses. Multicore-optimized workflow diamond blocking for optimizing stencil updates. *SIAM Journal on Scientific Computing*. 37(4):C439–C464, 10 2015. doi: 10.1137/140991133.

[3] S. Williams, A. Waterman, and D. Patterson. Roofline: An insightful visual performance model for multicore architectures. *Commun. ACM*, 52(4):65–76, 2009. doi: 10.1145/1498765.1498765.

[4] J. Treibig, G. Hager, and G. Wellein. LKWD: A lightweight performance-oriented tool suite for x86 multicore environments. In *IPDPS: 15th Proceedings of the 6th International Workshop on Performance Modeling, Benchmarking, and Simulation of High Performance Computing Systems*. San Diego CA, September 13, 2010. doi: 10.1109/IPDPSW.2010.38.

[5] Gabriel Rivera and Chao-Wen Teng. Tiling optimizations for 3D scientific computations. In *Proceedings of the 2000 ACM/IEEE conference on Supercomputing (ISO '00)*. IEEE, doi: 10.1109/iscc.2000.10015.

Kerncraft^[1]

Kernel Code

Standard compliant C99 code, with no additional branches in loops.

3D-long-range kernel code^[2], as used for following examples:

```
double U[M][N][N], V[M][N][N], ROC[M][N][N];
double c0, c1, c2, c3, c4, lap;

for(int k=4; k < M-4; k++) { for(int j=4; j < N-4; j++) { for(int i=4; i < N-4; i++) {
    lap = c0 * V[k][j][i]
    + c1 * (V[k][j][j+1] + V[k][j][j-1] + V[k][j+1][i] + V[k][j-1][i] + V[k+1][j][i] + V[k-1][j][i] + V[k][j+2][i] + V[k][j-2][i] + V[k+2][j][i] + V[k-2][j][i] + V[k][j+3][i] + V[k][j-3][i] + V[k+3][j][i] + V[k-3][j][i] + V[k][j+4][i] + V[k][j-4][i] + V[k+4][j][i] + V[k-4][j][i] + V[k][j+5][i] + V[k][j-5][i] + V[k+5][j][i] + V[k-5][j][i] + V[k][j+6][i] + V[k][j-6][i] + V[k+6][j][i] + V[k-6][j][i] + V[k][j+7][i] + V[k][j-7][i] + V[k+7][j][i] + V[k-7][j][i] + V[k][j+8][i] + V[k][j-8][i] + V[k+8][j][i] + V[k-8][j][i] + V[k][j+9][i] + V[k][j-9][i] + V[k+9][j][i] + V[k-9][j][i] + V[k][j+10][i] + V[k][j-10][i] + V[k+10][j][i] + V[k-10][j][i] + V[k][j+11][i] + V[k][j-11][i] + V[k+11][j][i] + V[k-11][j][i] + V[k][j+12][i] + V[k][j-12][i] + V[k+12][j][i] + V[k-12][j][i] + V[k][j+13][i] + V[k][j-13][i] + V[k+13][j][i] + V[k-13][j][i] + V[k][j+14][i] + V[k][j-14][i] + V[k+14][j][i] + V[k-14][j][i] + V[k][j+15][i] + V[k][j-15][i] + V[k+15][j][i] + V[k-15][j][i] + V[k][j+16][i] + V[k][j-16][i] + V[k+16][j][i] + V[k-16][j][i] + V[k][j+17][i] + V[k][j-17][i] + V[k+17][j][i] + V[k-17][j][i] + V[k][j+18][i] + V[k][j-18][i] + V[k+18][j][i] + V[k-18][j][i] + V[k][j+19][i] + V[k][j-19][i] + V[k+19][j][i] + V[k-19][j][i] + V[k][j+20][i] + V[k][j-20][i] + V[k+20][j][i] + V[k-20][j][i] + V[k][j+21][i] + V[k][j-21][i] + V[k+21][j][i] + V[k-21][j][i] + V[k][j+22][i] + V[k][j-22][i] + V[k+22][j][i] + V[k-22][j][i] + V[k][j+23][i] + V[k][j-23][i] + V[k+23][j][i] + V[k-23][j][i] + V[k][j+24][i] + V[k][j-24][i] + V[k+24][j][i] + V[k-24][j][i] + V[k][j+25][i] + V[k][j-25][i] + V[k+25][j][i] + V[k-25][j][i] + V[k][j+26][i] + V[k][j-26][i] + V[k+26][j][i] + V[k-26][j][i] + V[k][j+27][i] + V[k][j-27][i] + V[k+27][j][i] + V[k-27][j][i] + V[k][j+28][i] + V[k][j-28][i] + V[k+28][j][i] + V[k-28][j][i] + V[k][j+29][i] + V[k][j-29][i] + V[k+29][j][i] + V[k-29][j][i] + V[k][j+30][i] + V[k][j-30][i] + V[k+30][j][i] + V[k-30][j][i] + V[k][j+31][i] + V[k][j-31][i] + V[k+31][j][i] + V[k-31][j][i] + 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V[k][j+94][i] + V[k][j-94][i] + V[k+94][j][i] + V[k-94][j][i] + V[k][j+95][i] + V[k][j-95][i] + V[k+95][j][i] + V[k-95][j][i] + V[k][j+96][i] + V[k][j-96][i] + V[k+96][j][i] + V[k-96][j][i] + V[k][j+97][i] + V[k][j-97][i] + V[k+97][j][i] + V[k-97][j][i] + V[k][j+98][i] + V[k][j-98][i] + V[k+98][j][i] + V[k-98][j][i] + V[k][j+99][i] + V[k][j-99][i] + V[k+99][j][i] + V[k-99][j][i] + V[k][j+100][i] + V[k][j-100][i] + V[k+100][j][i] + V[k-100][j][i] + V[k][j+101][i] + V[k][j-101][i] + V[k+101][j][i] + V[k-101][j][i] + V[k][j+102][i] + V[k][j-102][i] + V[k+102][j][i] + V[k-102][j][i] + V[k][j+103][i] + V[k][j-103][i] + V[k+103][j][i] + V[k-103][j][i] + V[k][j+104][i] + V[k][j-104][i] + V[k+104][j][i] + V[k-104][j][i] + V[k][j+105][i] + V[k][j-105][i] + V[k+105][j][i] + V[k-105][j][i] + V[k][j+106][i] + V[k][j-106][i] + V[k+106][j][i] + V[k-106][j][i] + V[k][j+107][i] + V[k][j-107][i] + V[k+107][j][i] + V[k-107][j][i] + V[k][j+108][i] + V[k][j-108][i] + V[k+108][j][i] + V[k-108][j][i] + 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+ V[k-123][j][i] + V[k][j+124][i] + V[k][j-124][i] + V[k+124][j][i] + V[k-124][j][i] + V[k][j+125][i] + V[k][j-125][i] + V[k+125][j][i] + V[k-125][j][i] + V[k][j+126][i] + V[k][j-126][i] + V[k+126][j][i] + V[k-126][j][i] + V[k][j+127][i] + V[k][j-127][i] + V[k+127][j][i] + V[k-127][j][i] + V[k][j+128][i] + V[k][j-128][i] + V[k+128][j][i] + V[k-128][j][i] + V[k][j+129][i] + V[k][j-129][i] + V[k+129][j][i] + V[k-129][j][i] + V[k][j+130][i] + V[k][j-130][i] + V[k+130][j][i] + V[k-130][j][i] + V[k][j+131][i] + V[k][j-131][i] + V[k+131][j][i] + V[k-131][j][i] + V[k][j+132][i] + V[k][j-132][i] + V[k+132][j][i] + V[k-132][j][i] + V[k][j+133][i] + V[k][j-133][i] + V[k+133][j][i] + V[k-133][j][i] + V[k][j+134][i] + V[k][j-134][i] + V[k+134][j][i] + V[k-134][j][i] + V[k][j+135][i] + V[k][j-135][i] + V[k+135][j][i] + V[k-135][j][i] + V[k][j+136][i] + V[k][j-136][i] + V[k+136][j][i] + V[k-136][j][i] + V[k][j+137][i] + V[k][j-137][i] + V[k+137][j][i] + V[k-137][j][i] + V[k][j+138][i] + V[k][j-138][i] + V[k+138][j][i] + V[k-138][j][i] + V[k][j+139][i] + V[k][j-139][i] + V[k+139][j][i] + V[k-139][j][i] + V[k][j+140][i] + V[k][j-140][i] + V[k+140][j][i] + V[k-140][j][i] + V[k][j+141][i] + V[k][j-141][i] + V[k+141][j][i] + V[k-141][j][i] + V[k][j+142][i] + V[k][j-142][i] + V[k+142][j][i] + V[k-142][j][i] + V[k][j+143][i] + V[k][j-143][i] + V[k+143][j][i] + V[k-143][j][i] + V[k][j+144][i] + V[k][j-144][i] + V[k+144][j][i] + V[k-144][j][i] + V[k][j+145][i] + V[k][j-145][i] + V[k+145][j][i] + V[k-145][j][i] + V[k][j+146][i] + V[k][j-146][i] + V[k+146][j][i] + V[k-146][j][i] + V[k][j+147][i] + V[k][j-147][i] + V[k+147][j][i] + V[k-147][j][i] + V[k][j+148][i] + V[k][j-148][i] + V[k+148][j][i] + V[k-148][j][i] + V[k][j+149][i] + V[k][j-149][i] + V[k+149][j][i] + V[k-149][j][i] + V[k][j+150][i] + V[k][j-150][i] + V[k+150][j][i] + V[k-150][j][i] + V[k][j+151][i] + V[k][j-151][i] + V[k+151][j][i] + V[k-151][j][i] + V[k][j+152][i] + V[k][j-152][i] + V[k+152][j][i] + V[k-152][j][i] + V[k][j+153][i] + V[k][j-153][i] + V[k+153][j][i] + V[k-153][j][i] + V[k][j+154][i] + V[k][j-154][i] + V[k+154][j][i] + V[k-154][j][i] + V[k][j+155][i] + V[k][j-155][i] + V[k+155][j][i] + V[k-155][j][i] + V[k][j+156][i] + V[k][j-156][i] + V[k+156][j][i] + V[k-156][j][i] + V[k][j+157][i] + V[k][j-157][i] + V[k+157][j][i] + V[k-157][j][i] + V[k][j+158][i] + V[k][j-158][i] + V[k+158][j][i] + V[k-158][j][i] + V[k][j+159][i] + V[k][j-159][i] + V[k+159][j][i] + V[k-159][j][i] + V[k][j+160][i] + V[k][j-160][i] + V[k+160][j][i] + V[k-160][j][i] + V[k][j+161][i] + V[k][j-161][i] + V[k+161][j][i] + V[k-161][j][i] + V[k][j+162][i] + V[k][j-162][i] + V[k+162][j][i] + V[k-162][j][i] + V[k][j+163][i] + V[k][j-163][i] + V[k+163][j][i] + V[k-163][j][i] + V[k][j+164][i] + V[k][j-164][i] + V[k+164][j][i] + V[k-164][j][i] + V[k][j+165][i] + V[k][j-165][i] + V[k+165][j][i] + V[k-165][j][i] + V[k][j+166][i] + V[k][j-166][i] + V[k+166][j][i] + V[k-166][j][i] + V[k][j+167][i] + V[k][j-167][i] + V[k+167][j][i] + V[k-167][j][i] + V[k][j+168][i] + V[k][j-168][i] + V[k+168][j][i] + V[k-168][j][i] + V[k][j+169][i] + V[k][j-169][i] + V[k+169][j][i] + V[k-169][j][i] + V[k][j+170][i] + V[k][j-170][i] + V[k+170][j][i] + V[k-170][j][i] + V[k][j+171][i] + V[k][j-171][i] + V[k+171][j][i] + V[k-171][j][i] + V[k][j+172][i] + V[k][j-172][i] + V[k+172][j][i] + V[k-172][j][i] + V[k][j+173][i] + V[k][j-173][i] + V[k+173][j][i] + V[k-173][j][i] + V[k][j+174][i] + V[k][j-174][i] + V[k+174][j][i] + V[k-174][j][i] + V[k][j+175][i] + V[k][j-175][i] + V[k+175][j][i] + V[k-175][j][i] + V[k][j+176][i] + V[k][j-176][i] + V[k+176][j][i] + V[k-176][j][i] + V[k][j+177][i] + V[k][j-177][i] + V[k+177][j][i] + V[k-177][j][i] + V[k][j+178][i] + V[k][j-178][i] + V[k+178][j][i] + V[k-178][j][i] + V[k][j+179][i] + V[k][j-179][i] + V[k+179][j][i] + V[k-179][j][i] + V[k][j+180][i] + V[k][j-180][i] + V[k+180][j][i] + V[k-180][j][i] + V[k][j+181][i] + V[k][j-181][i] + V[k+181][j][i] + V[k-181][j][i] + V[k][j+182][i] + V[k][j-182][i] + V[k+182][j][i] + V[k-182][j][i] + V[k][j+183][i] + V[k][j-183][i] + V[k+183][j][i] + V[k-183][j][i] + V[k][j+184][i] + V[k][j-184][i] + V[k+184][j][i] + V[k-184][j][i] + V[k][j+185][i] + V[k][j-185][i] + V[k+185][j][i] + V[k-185][j][i] + V[k][j+186][i] + V[k][j-186][i] + V[k+186][j][i] + V[k-186][j][i] + V[k][j+187][i] + V[k][j-187][i] + V[k+187][j][i] + V[k-187][j][i] + V[k][j+188][i] + V[k][j-188][i] + V[k+188][j][i] + V[k-188][j][i] + V[k][j+189][i] + V[k][j-189][i] + V[k+189][j][i] + V[k-189][j][i] + V[k][j+190][i] + V[k][j-190][i] + V[k+190][j][i] + V[k-190][j][i] + V[k][j+191][i] + V[k][j-191][i] + V[k+191][j][i] + V[k-191][j][i] + V[k][j+192][i] + V[k][j-192][i] + V[k+192][j][i] + V[k-192][j][i] + V[k][j+193][i] + V[k][j-193][i] + V[k+193][j][i] + V[k-193][j][i] + V[k][j+194][i] + V[k][j-194][i] + V[k+194][j][i] + V[k-194][j][i] + V[k][j+195][i] + V[k][j-195][i] + V[k+195][j][i] + V[k-195][j][i] + V[k][j+196][i] + V[k][j-196][i] + V[k+196][j][i] + V[k-196][j][i] + V[k][j+197][i] + V[k][j-197][i] + V[k+197][j][i] + V[k-197][j][i] + V[k][j+198][i] + V[k][j-198][i] + V[k+198][j][i] + V[k-198][j][i] + V[k][j+199][i] + V[k][j-199][i] + V[k+199][j][i] + V[k-199][j][i] + V[k][j+200][i] + V[k][j-200][i] + V[k+200][j][i] + V[k-200][j][i] + V[k][j+201][i] + V[k][j-201][i] + V[k+201][j][i] + V[k-201][j][i] + V[k][j+202][i] + V[k][j-202][i] + V[k+202][j][i] + V[k-202][j][i] + V[k][j+203][i] + V[k][j-203][i] + V[k+203][j][i] + V[k-203][j][i] + V[k][j+204][i] + V[k][j-204][i] + V[k+204][j][i] + V[k-204][j][i] + V[k][j+205][i] + V[k][j-205][i] + V[k+205][j][i] + V[k-205][j][i] + V[k][j+206][i] + V[k][j-206][i] + V[k+206][j][i] + V[k-206][j][i] + V[k][j+207][i] + V[k][j-207][i] + V[k+207][j][i] + V[k-207][j][i] + V[k][j+208][i] + V[k][j-208][i] + V[k+208][j][i] + V[k-208][j][i] + V[k][j+209][i] + V[k][j-209][i] + V[k+209][j][i] + V[k-209][j][i] + V[k][j+210][i] + V[k][j-210][i] + V[k+210][j][i] + V[k-210][j][i] + V[k][j+211][i] + V[k][j-211][i] + V[k+211][j][i] + V[k-211][j][i] + V[k][j+212][i] + V[k][j-212][i] + V[k+212][j][i] + V[k-212][j][i] + V[k][j+213][i] + V[k][j-213][i] + V[k+213][j][i] + V[k-213][j][i] + V[k][j+214][i] + V[k][j-214][i] + V[k+214][j][i] + V[k-214][j][i] + V[k][j+215][i] + V[k][j-215][i] + V[k+215][j][i] + V[k-215][j][i] + V[k][j+216][i] + V[k][j-216][i] + V[k+216][j][i] + V[k-216][j][i] + V[k][j+217][i] + V[k][j-217][i] + V[k+217][j][i] + V[k-217][j][i] + V[k][j+218][i] + V[k][j-218][i] + V[k+218][j][i] + V[k-218][j][i] + V[k][j+219][i] + V[k][j-219][i] + V[k+219][j][i] + V[k-219][j][i] + V[k][j+220][i] + V[k][j-220][i] + V[k+220][j][i] + V[k-220][j][i] + V[k][j+221][i] + V[k][j-221][i] + V[k+221][j][i] + V[k-221][j][i] + V[k][j+222][i] + V[k][j-222][i] + V[k+222][j][i] + V[k-222][j][i] + V[k][j+223][i] + V[k][j-223][i] + V[k+223][j][i] + V[k-223][j][i] + V[k][j+224][i] + V[k][j-224][i] + V[k+224][j][i] + V[k-224][j][i] + V[k][j+225][i] + V[k][j-225
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