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Accelerating Medoids-based Clustering with the Intel Many Integrated Core Architecture

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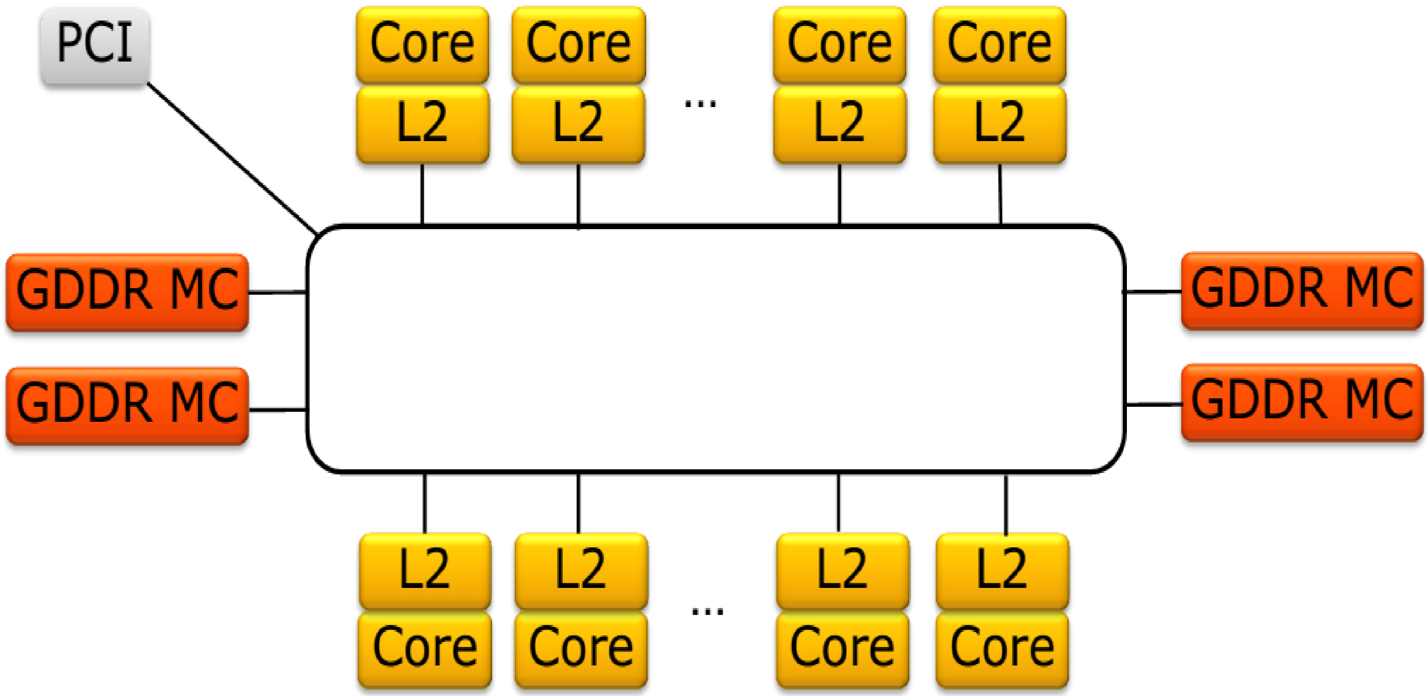
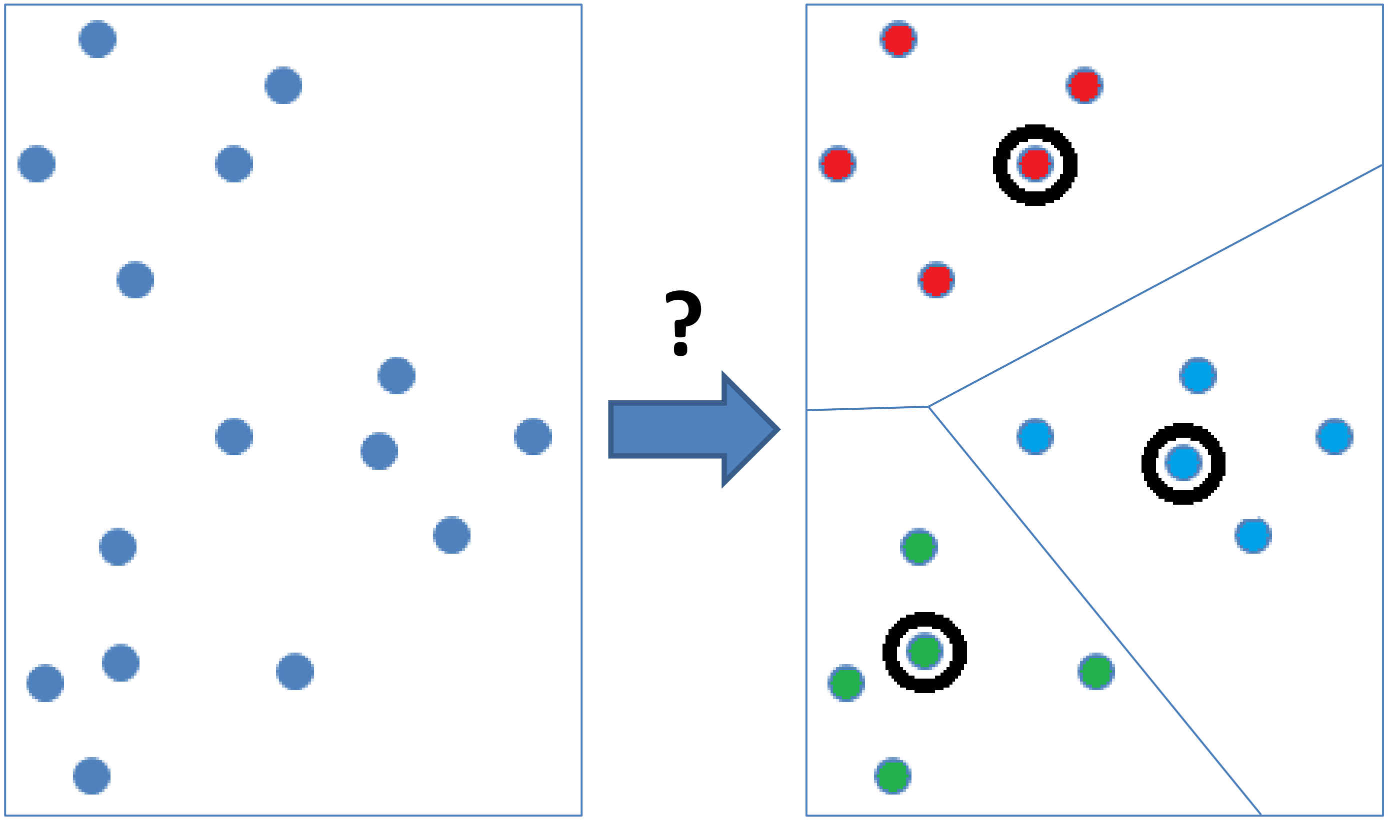
Intel Xeon Phi



Partitioning Clustering



PAM properties

- *PAM algorithm (Partitioning Around Medoids)* – partitioning clustering algorithm which selects cluster centers among clustered objects
- Such objects called *medoids*
- Iteration time complexity is $O(k(n\text{-}k)^2)$, where
  - n is the number of clustered objects
  - k is the number of clusters

Objective function

- Objective function

$$E = \sum_{j=1}^{n} \min_{1 \le i \le k} \rho(c_i, o_j).$$

, where c_i is the medoid, o_j is the clustered object, ρ is the distance metric

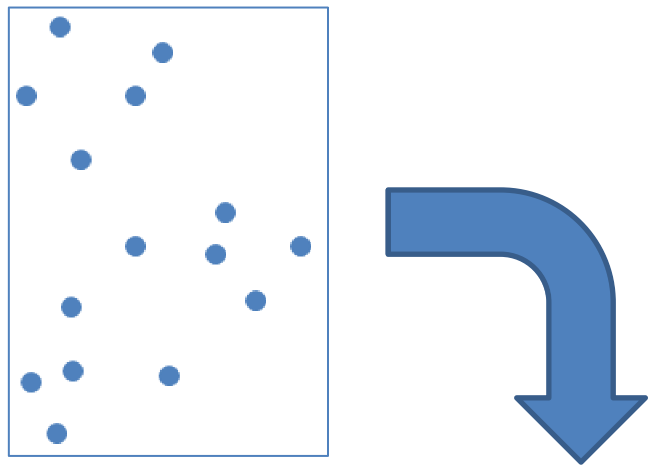
PAM pseudocode

Input: Set of objects O, number of clusters k

Output: Set of clusters C

1. Initialize C; // BUILD phase
2. **repeat** // SWAP phase
3. Find best swapping estimation T_{min};
4. Swap c_{min} and o_{min}, determined by T_{min};
5. **until** $T_{min} < 0$;

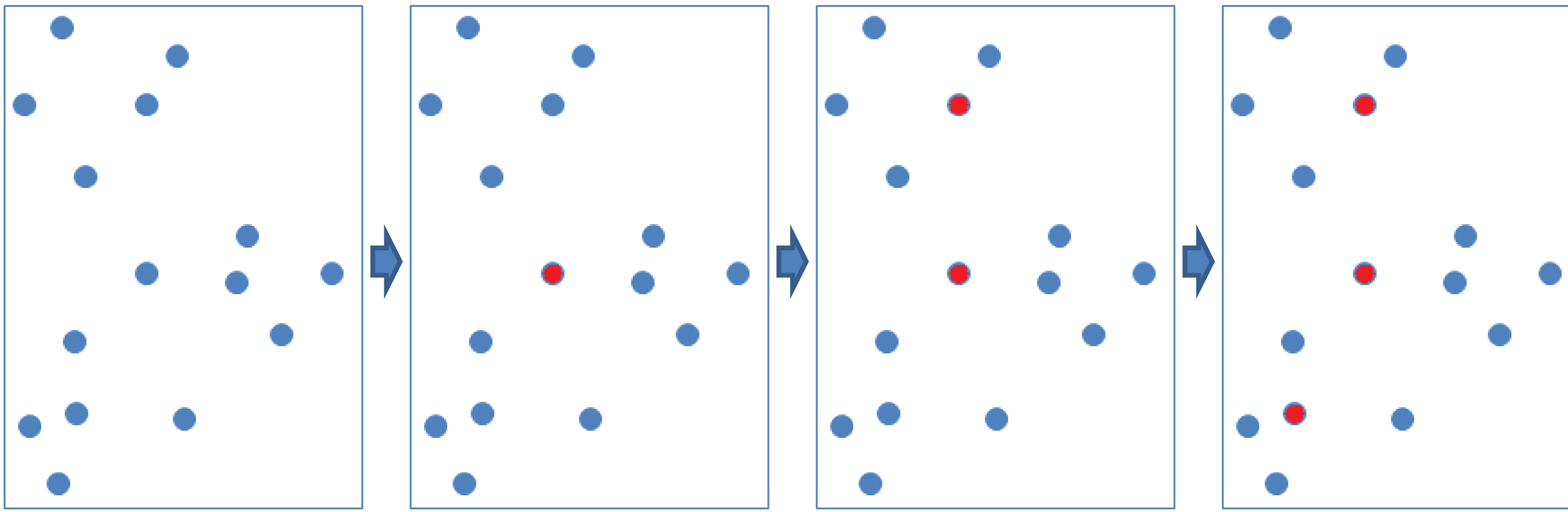
Calculating distance matrix



	o_1	o_2	o_3	…	o_n
o_1	$\rho(o_1,o_1)$	$\rho(o_1,o_2)$	$\rho(o_1,o_3)$	…	$\rho(o_1,o_n)$
o_2	$\rho(o_2,o_1)$	$\rho(o_2,o_2)$	$\rho(o_2,o_3)$	…	$\rho(o_2,o_n)$
o_3	$\rho(o_3,o_1)$	$\rho(o_3,o_2)$	$\rho(o_3,o_3)$	…	$\rho(o_3,o_n)$
…	…	…	…	…	…
o_n	$\rho(o_n,o_1)$	$\rho(o_n,o_2)$	$\rho(o_n,o_3)$	…	$\rho(o_n,o_n)$

BUILD phase

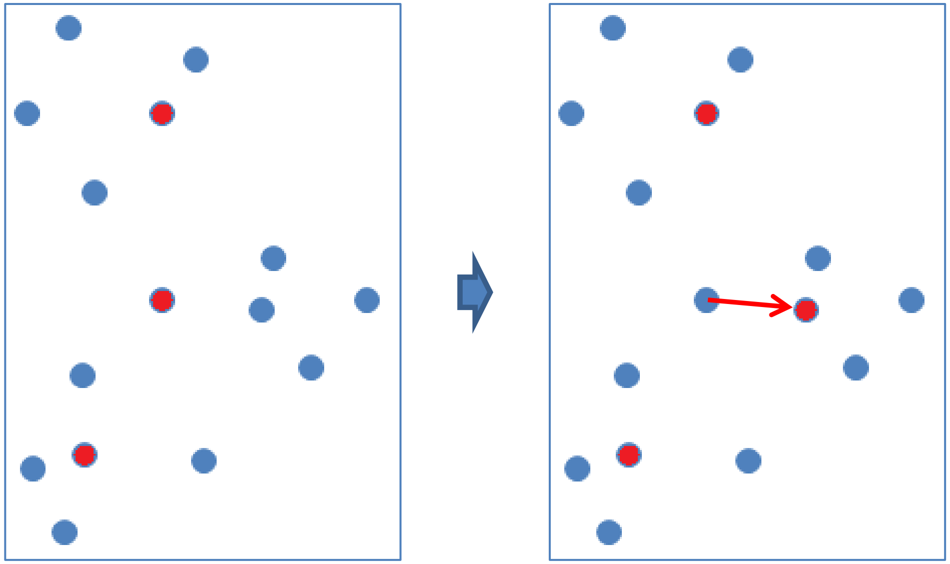
k=3



$E=\infty$ $E= 2{,}250$ $E= 1{,}578$ $E= 1{,}014$

Time complexity $O(kn^2)$

SWAP phase



E= 1,014 *E*= 0,865

Time complexity $O(k(n - k)^2)$ per iteration

Used Optimizations

- Parallelizing with OpenMP
- Loops with arithmetic operations were reorganized for vectorized execution
  - Data consists of 32 element blocks
- Tiling for better locality and cache performance

PAM implementation

Input: Set of objects *O*, number of clusters *k*

Output: Set of clusters *C*

1. M <- PrepareDistanceMatrix(O);
2. C <- BuildMedoids(M); // BUILD phase
3. **repeat** // SWAP phase
4. T_{min} <- FindBestSwap(M, C);
5. Swap c_{min} and o_{min}, determined by T_{min};
6. **until** $T_{min} < 0$;

Experimental evaluation

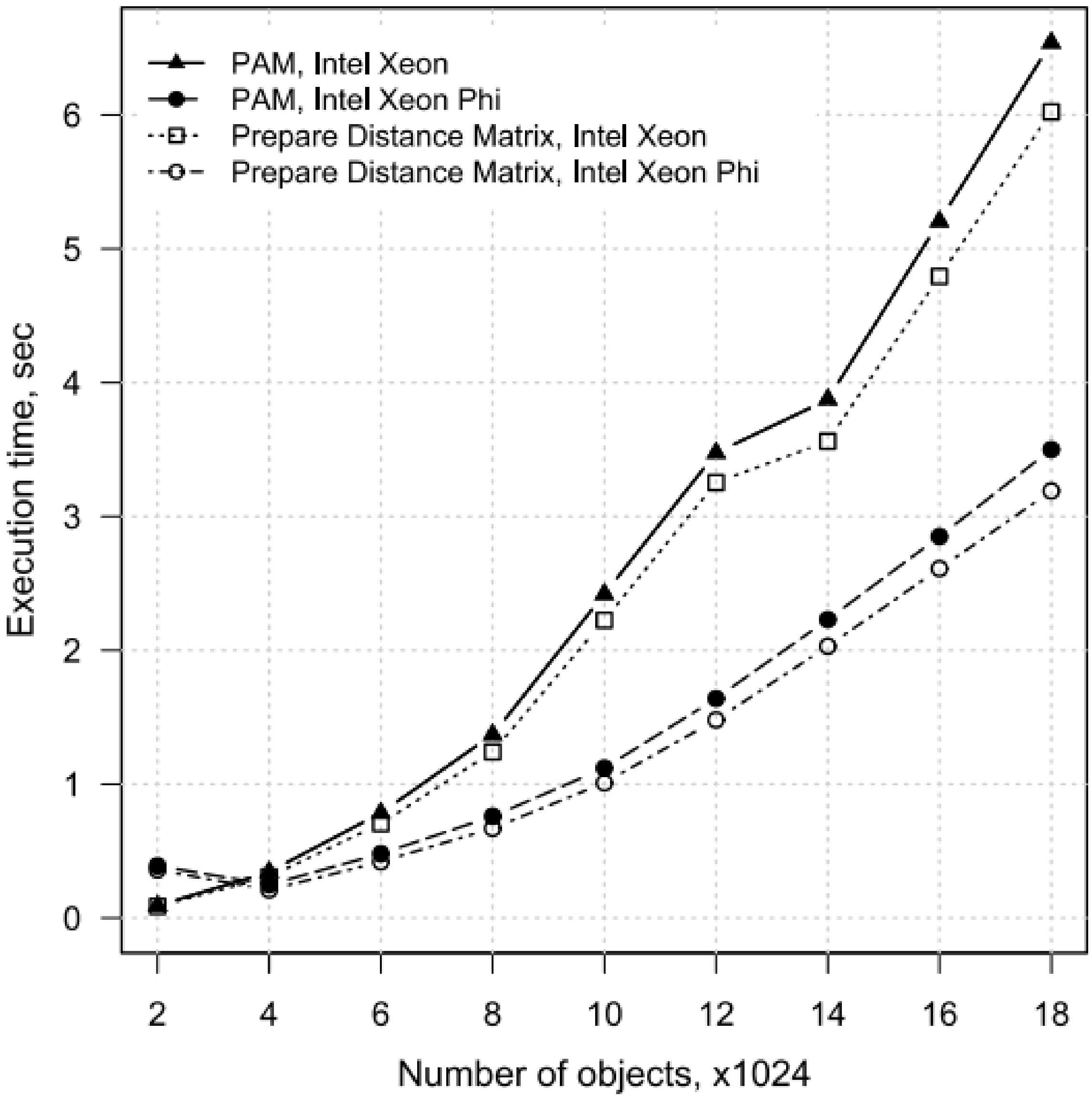
- Hardware
  - Intel Xeon Phi 60 cores
  - Intel Xeon 12 cores
- Parameters
  - Data type: float
  - Intel Xeon Phi mode: offload
- Purpose
  - Compare work time of PAM algorithm on CPU and Intel Xeon Phi

Dataset properties

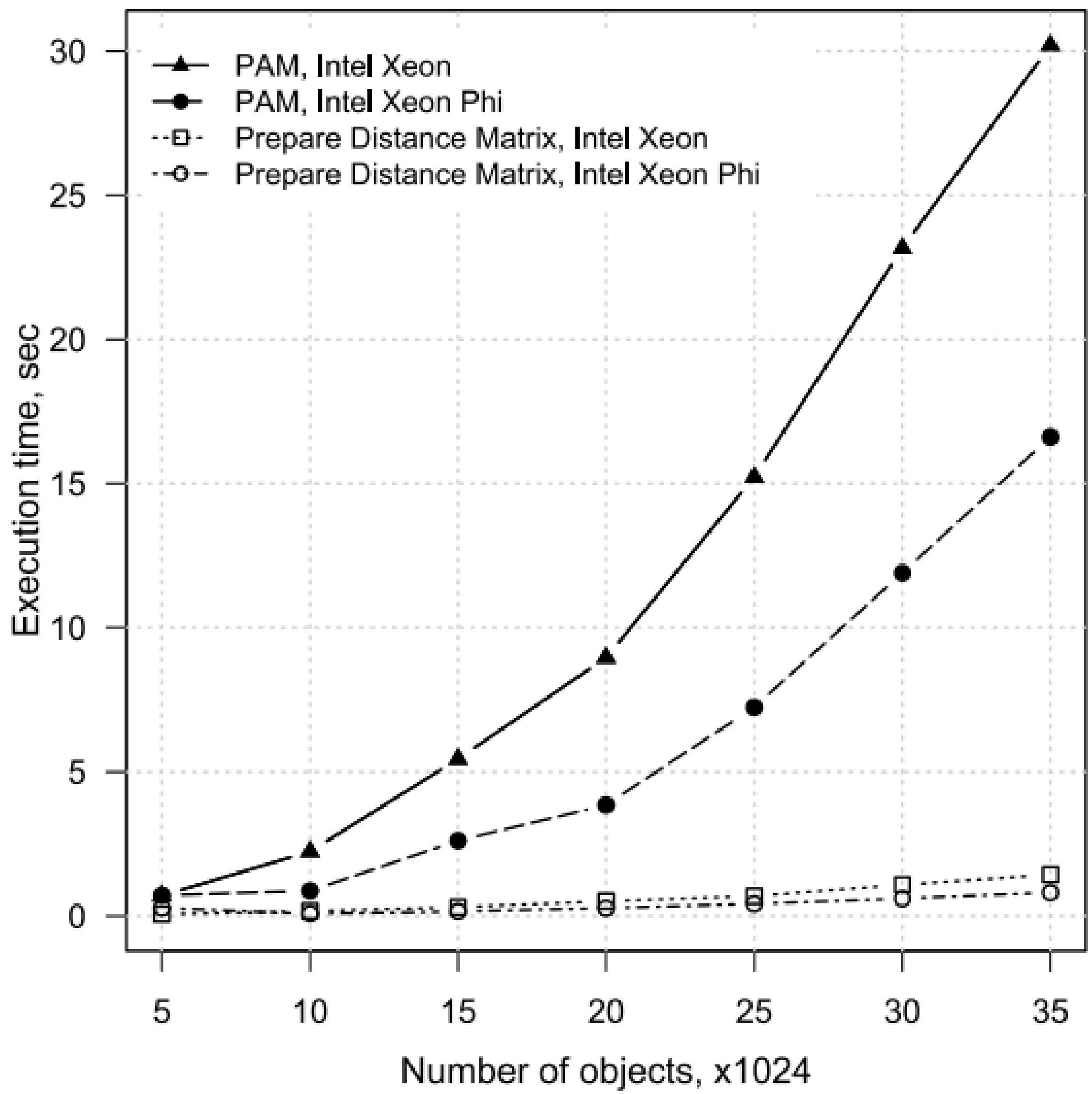
Dataset	p	k	$n, \times 2^{10}$	
			min	max
FCS Human	423	10	2	18
Corel Image Histogram	32	10	5	35

- p – size of real-valued tuple which describes clustering object
- k – the number of clusters
- n – the number of clustering objects

FCS Human evaluation



Corel Image Histogram evaluation



Conclusion

- The paper has described a parallel version of Partitioning Around Medoids clustering algorithm for the Intel Xeon Phi many-core coprocessor
  – OpenMP
  – Vectorization
  – Tiling
- Experimental results show effectiveness of suggested approach
- Experiments show that PAM performance depends on clustered data nature