

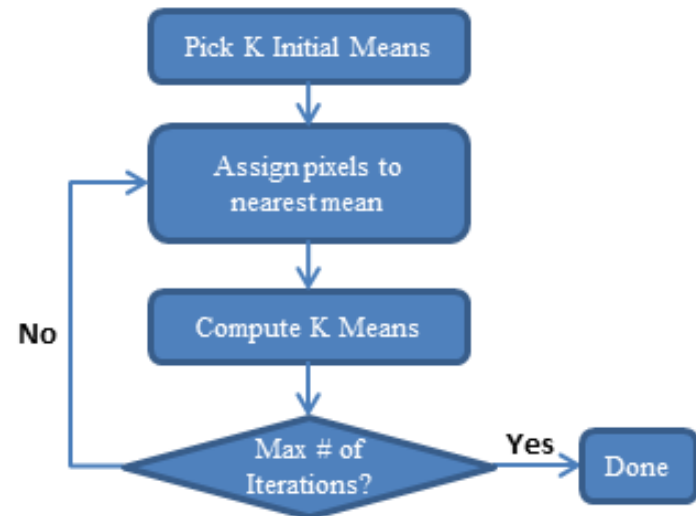
# FPGA-based Acceleration of Hyperspectral K-Means Clustering



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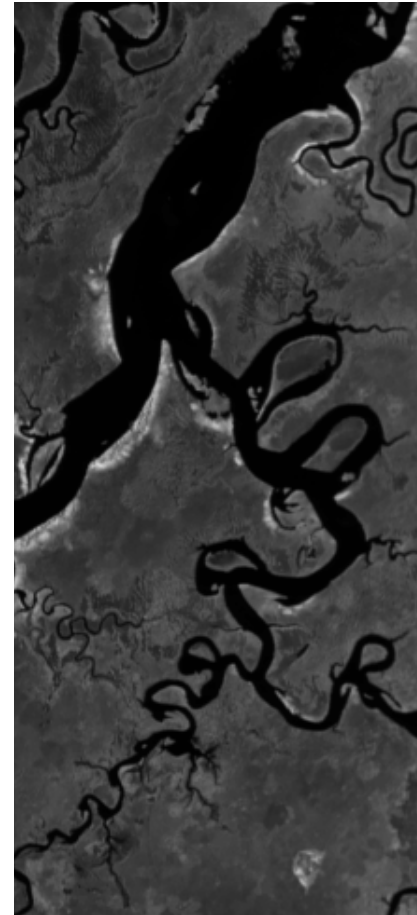
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- **K-means clustering**
  - An unsupervised and iterative clustering algorithm
  - Clusters N observations into K clusters
    - Observations assigned to cluster with nearest mean
    - Cluster means adjusted to average of current members
    - Number of iterations can be fixed, or a termination criterion can be used to end clustering
    - Our research uses fixed iterations

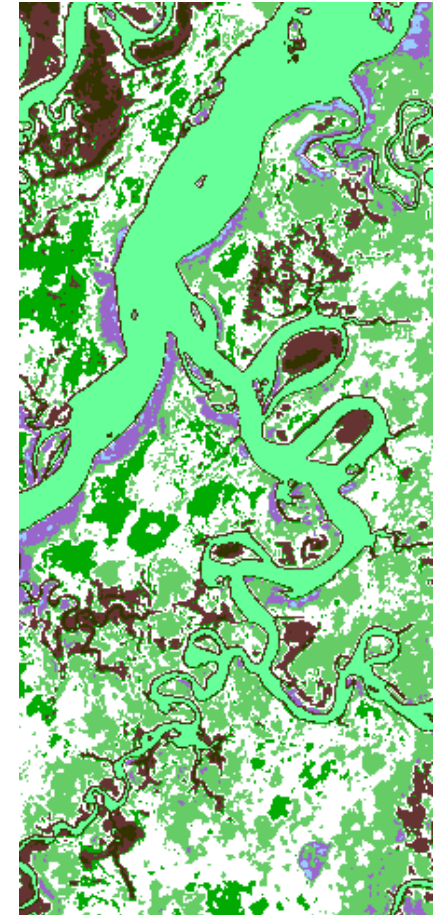


**K-Means Clustering Algorithm**

- K-means clustering is useful in determining spectrally similar pixels in multi/hyperspectral images
- All computations can be performed using an FPGA
- The current research clusters eight spectral channels from a 360-band hyperspectral image into eight clusters

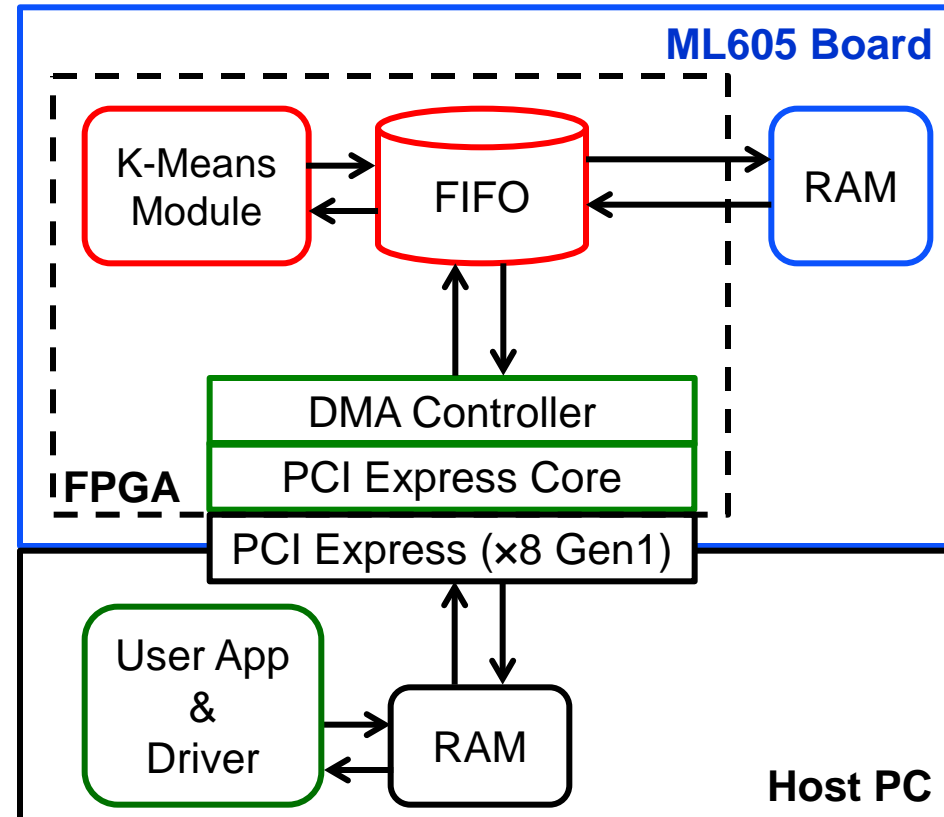


**Eight-Channel Test  
Image  
(Single Band Shown)**



**K-Means  
Clustered Image  
(Eight Clusters)**

- **FPGA implementation by Wang exploits parallelism of k-means calculations [1]**
  - Pixel-to-cluster mean distances computed in parallel for all clusters
  - Adder and comparator trees, etc. used to lower latency
- **Current research utilizes updated VHDL design on ML605 board with Virtex6 FPGA to improve performance**
  - PCI Express and high-speed FIFO used for data transfer to/from DDR3 memory on ML605
  - Latest version of Northeastern University's Variable Precision Floating Point (VFLOAT) library integrated into design



- Performance estimates from software k-means clustering versus FPGA k-means clustering simulations
- PCI Express for data transfer enables streaming pixel data during algorithm execution
  - FPGA total speedup now limited by k-means computation time for larger problem sizes

Iter.	SW Compute (s)	SW Total (s)	FPGA Compute & Transfer (s)	FPGA Compute Speedup (x)	FPGA Total Speedup (x)
1	0.093	2.68	0.0025	37.1	1079
20	1.90	4.52	0.0503	37.8	89.9
50	4.75	7.36	0.126	37.8	58.6
1000	95.4	98.0	2.52	37.9	39
5000	475	478	12.6	37.8	38

## References

- [1] X. Wang and M. Leeser, "VFloat: A Variable Precision Fixed- and Floating-Point Library for Reconfigurable Hardware," *ACM Transactions on Reconfigurable Technology and Systems*, Vol. 3, No. 3, September 2010.