Application of Fully Parallel Associative Memory in Two-Stage Pattern Matching

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Nanoelectronics for Tera-bit Information Processing

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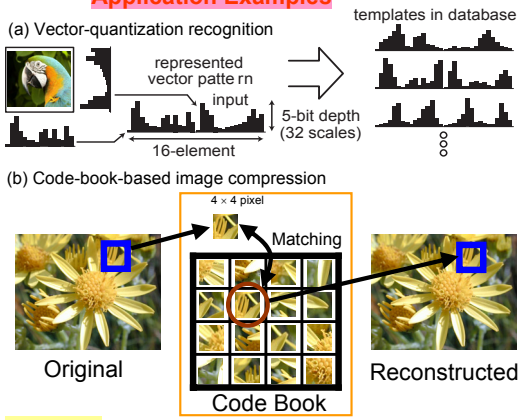
Introduction

Motivation

- To find the nearest match for an input-data of W-bit length among R reference data words with a fully parallel processing.
- Euclidean distance measure is advantageous in terms of giving an actual distance between two points in the real space.
- Two-stage winner search system significantly improves the reliability of pattern matching or vector quantization recognition.

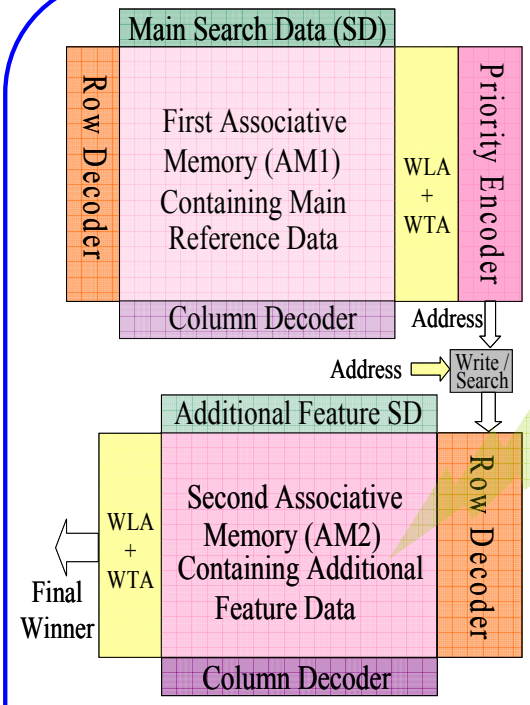
Application Examples



Features

- The realization of *k*-nearest-matches search capability in fully-parallel mixed digital-analog associative memories by a sequential autonomous search mode is reported.
- The proposed concept and circuit implementation can be applied with all types of distance measures such as Hamming, Manhattan or Euclidean distance search.
- The value of k is arbitrarily selectable during operation.

Two-Stage Pattern Matching System

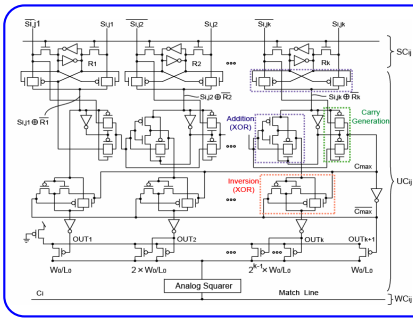


Additional Feature data may contains the features like:

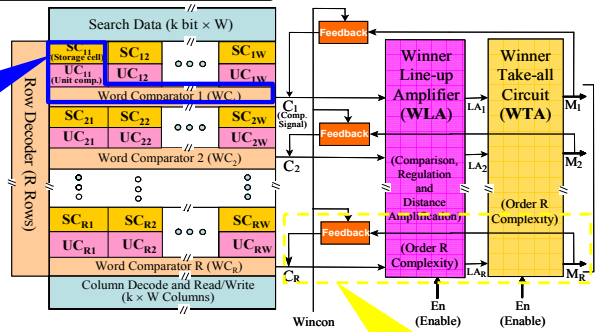
1. Total mass
   (no. of black pixels)
2. Centroid
   (average of horizontal and vertical projections)
3. Eccentricity
   (ratio of major to minor axis)
4. Orientation
   (angle of major axis)
5. Skewness

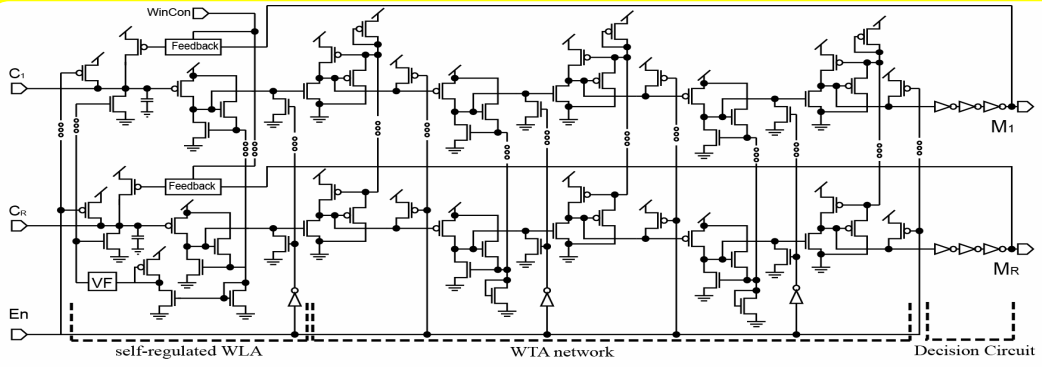
- The two-stage pattern matching system consists of two associative memory blocks, one for the main reference data and another for additional feature reference data.
- Hybrid distance measures like Hamming/Manhattan distance in the first associative memory and Euclidean distance in the second can be possible.
- After searching the first *k* nearest-matched reference patterns within the first associative memory and finding the nearest-match addresses, the corresponding lines in the additional feature memory will be activated for the final winner search. The second-stage winner search in the additional feature memory will be done among the *k* nearest-matched rows searched by the first associative memory.

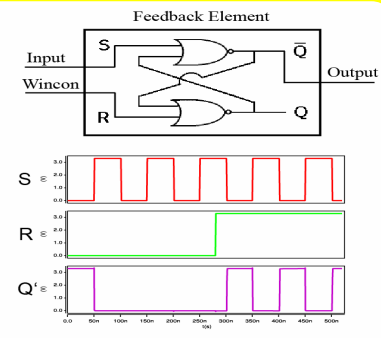
Architecture Circuit of the K-nearest-matches Search



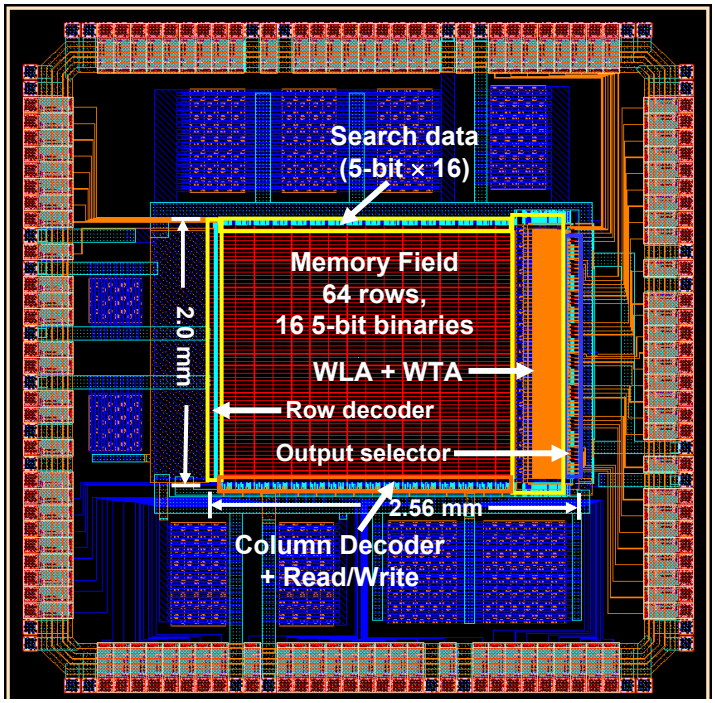
- k-bit digital subtractor and absolute value calculator and analog squarer are used to realize Euclidean distance search.
- All unit comparators and all word comparators calculate the distance between search word and stored word in parallel.





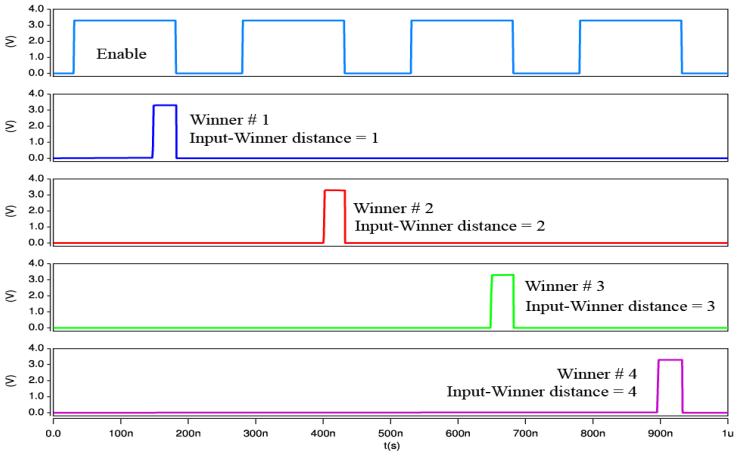


Layout Design and Simulated Performance



Specification of Test Chip

Distance Measure	Euclidean-Distance
Reference Patterns	64 Patterns (16 binaries each 5-bit long)
Design Area	5.12 mm² (2.56mm x 2mm)
Nearest Match Unit Area	0.64 mm² = 12.5% of design area
Chip size	4.9 mm × 4.9 mm
Chip pins	144
No. of Transistors	1,86,072
Technology	0.35 µm, 2-poly, 3-metal CMOS
Supply Voltage	3.3V

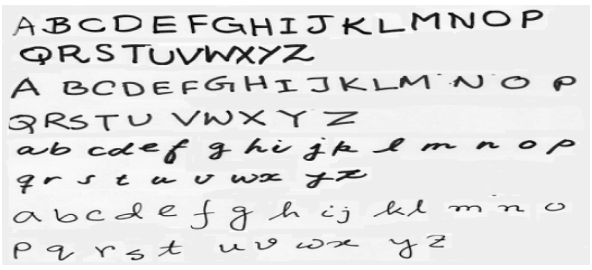


Output wave shapes of the K-nearest-matches search circuit

- The k-nearest-matches search system designed in 0.35 µm, two-poly, three-metal CMOS technology consumes only 5.12 mm2 area and contains 64 reference pattern with 16 binaries each 5-bit long.
- The k-nearest-matches search unit consumes only 0.64 mm2 which is 12.5% of the total design area.
- From the simulation result we can see that the first winner is searched in first clock cycle when the enable signal is high, after that the first winner becomes a loser during the entire simulation time. Similarly, in the next clock cycles the 2nd, 3rd, 4th winners up to a selectable *k* can be searched.

Simulation with MATLAB

Handwritten Samples from different writers



Classification Results

Writer	Test Set 1 (26 samples)		Test Set 2 (26 samples)	
	Miss-classify		Miss-classify	
	Single-stage	Two-stage	Single-stage	Two-stage
A	4	2	4	2
B	4	1	3	1
C	3	1	3	1
D	2	1	4	2
Total	12.5%	4.8%	13.5%	5.8%

- ❑ The proposed system has been tested and results are compared with the system which uses single stage recognition.
- ❑ The proposed system reduced the misclassification rate of the hand written character recognition system from 13% (with single stage) to 5.3%.

Conclusion

- 💻 A mixed digital-analog cascaded associative memory based system with two-stage winner search is proposed.
- 💻 Two-stage pattern matching system significantly improves the reliability of object recognition system.
- 💻 The proposed system reduced the misclassification rate of the hand written character recognition system from 13% (with single stage) to 5.3%.
- 💻 Since both the associative memories in the two-stage pattern matching system can be used for different distance measures, it is possible to implement a hybrid distance measure.