# FPGA Implementation of Object-Based Real-Time Object Tracking Architecture

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## Introduction

Moving Object Tracking is necessary for

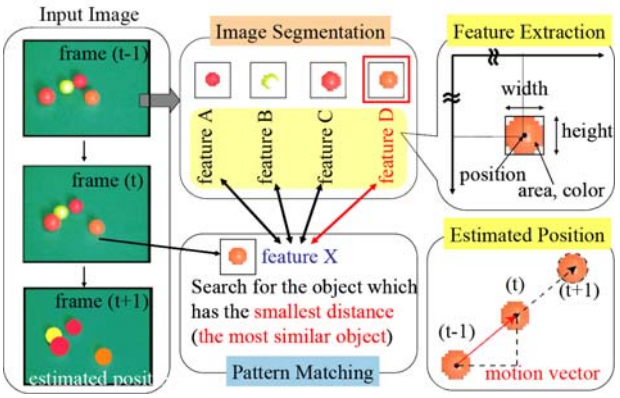
- Scene surveillance
- Object recognition etc…

Conventional Approach

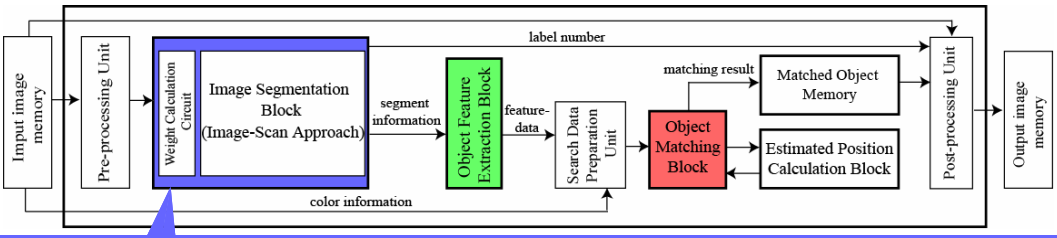
- Image difference method
  Processing is simple but this method has problems with following cases
  (1) Still objects tracking
  (2) Multiple moving objects tracking
  (3) Moving camera (background is moving)
  (4) Occlusion effect among objects
- Optical flow based method
  Real-time processing is difficult due to complex calculation

Proposed object tracking approach

- Image Segmentation
  Extracting meaningful regions from input video pictures.
  We use region-growing based image segmentation algorithm.
- Pattern Matching
  The most similar objects between successive frames are judged to be corresponding objects.

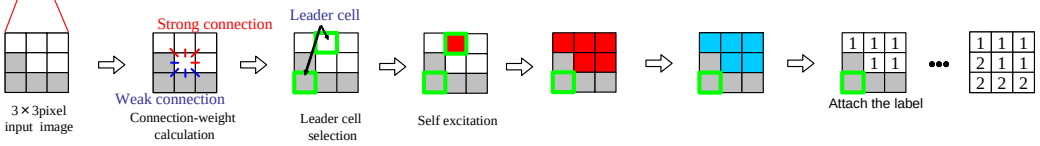



## Proposed object tracking architecture

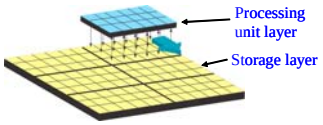



## Image Segmentation Algorithm (Region Growing Approach)

- Connection-weight calculation : Similarity of luminance between pixels
- Leader cell selection : Sum of connection weights with neighboring pixels has to be larger than a threshold
- Segmentation : Repeat self-excitation, excitation, and inhibition
- Attach the label : Result of the segmentation

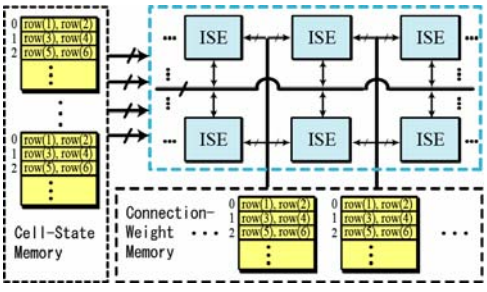



## Processing flow of Image-Scan Video Segmentation




- An input image is divided into smaller image blocks
- Each image block is processed sequentially with a processing unit layer

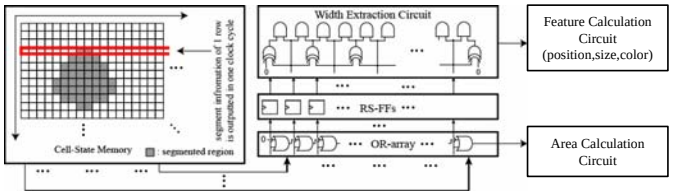
Feature
Trade-off between the processing time and hardware amount can be exploited




- All cell-state and connection-weight data for segmentation processing of m×2 pixels are stored in on-chip memory consisting of multi-banks, so that high access-bandwidth can be achieved.
- Address depth of each memory is corresponds to image block number. With this construction, the each flag and connection weights of one image block can be transmitted to image segmentation unit in 1 clock cycle.

## Object Feature Extraction Circuit

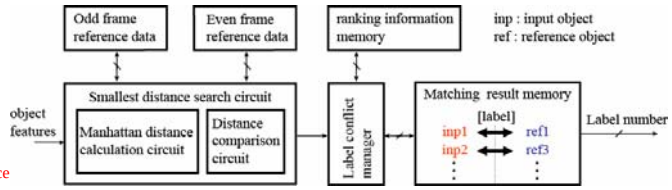
- The Cell-State Memory stores a 1 for pixels belonging to the current segment and otherwise 0.
- The segmented object boundaries between 1 or 0 are detected by Width Extraction Circuit and Height Extraction Circuit

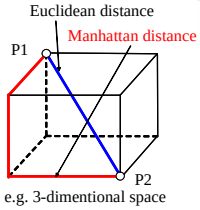



High speed feature extraction by using embedded memories

- Segmentation result is stored in high access-bandwidth embedded memories, which are constructed with multiple banks.
- We can access the segmentation result stored in a cell-state memory in row parallel in 1 clock cycle.

## Object Matching Circuit



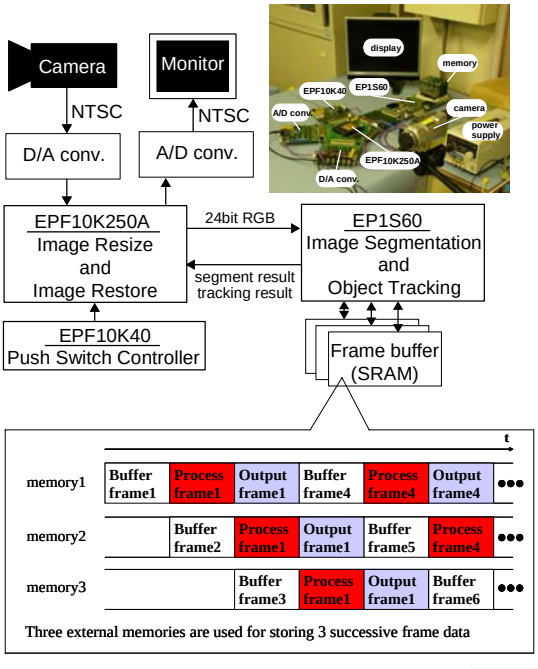

Distance in object feature space between
Object X = ($area_X$, $position_X$, $height_X$, $width_X$, $color_X$) and
Object Y = ($area_Y$, $position_Y$, $height_Y$, $width_Y$, $color_Y$)

• Manhattan distance ($D_M$) $D_{M\,X \Leftrightarrow Y}$ =

$|area_X - area_Y| + |position_X - position_Y| + \cdots + |color_X - color_Y|$

Matching quality of Manhattan distance is found to be approximately the same as with the more complicated Euclidean distance

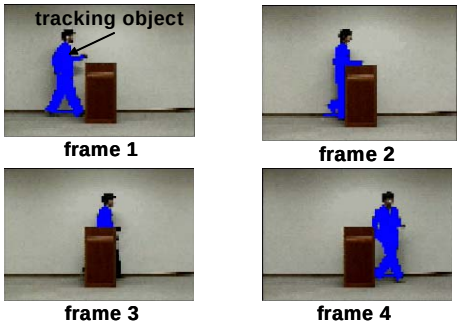
## FPGA-based real-time multi-object tracking prototype system




Specification of the developed system

| | | |
|---|---|---|
| Input/Output Signal | | NTSC Y/C Signal |
| Target Image Size | | 80×60 pixels |
| Processing Element Size | | 80×2 (2 line scan) |
| Clock Frequency | | 12.27 MHz |
| FPGA Devices | EP1S60 | LE: 31,008/57,120 (54%)<br>Mem: 0.17/5.2 Mbits (3%) |
| | EPF10K250A | LE: 157/12,160 (1%) |
| | EPF10K40 | LE: 162/2,304 (7%) |

Segmentation Result




## Conclusion

- We could confirm a correct object-tracking result and real-time processing of 30fps for the system.
- We have confirmed real time object tracking can be achieved by using this system.
- With the latest FPGA technology, the complete system can be implemented in a single FPGA.
- We have developed an FPGA-based object tracking system for verification of our proposed architecture.