Embedded Systems
CSEE W4840

Project Proposal

Hardware implementation of binary image processing to recognize gestures

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Overview:
Gesture based interfaces are often a more intuitive and user-friendly alternative to traditional key-based systems for the control and manipulation of devices.
We propose to develop a simple gesture recognition system on a FPGA that can identify a few simple hand gestures and thus provide the user with a more appealing way of interacting with devices.

For this project we will be capturing the images of hand gestures offline and focus on the development of a "real-time"/fast image processing algorithm that runs on a FPGA to recognize hand gestures. The images will be stored in the memory present on the Sockit board and be read into the FPGA when required.

The input images will be captured using a backlit setup to facilitate the easy generation of a binary image of the hand gesture with a simple fixed intensity threshold. We will then apply a series of binary image processing techniques to identify connected regions in the image and compute first and second order moments of each connected region. These computed moments will then be used to classify the hand gestures in a low dimensional feature space using a classifier like k-nearest neighbors that uses a Manhattan distance metric.

We propose to implement the thresholding, the binary image processing algorithms and the classifier on the FPGA. We believe that with use of look-up tables and a well pipelined design we would be able to get very fast implementations for our algorithm.

Binary image processing algorithm:

- Binary images are derived from grayscale images by selecting a threshold. The threshold is chosen empirically.

- Label the connected components of the binary image using the following steps:

  1. Scan through the image and select the first unlabeled pixel with b = 1.
  2. Set a new label for the chosen pixel and its neighbor with b = 1.
  3. Repeatedly use the same label for neighbors of neighbors with b =1 until no more unlabeled neighbors with b = 1 are found.

- Since we will be dealing with discrete binary images, following equations for calculation of object properties will be used in our algorithm:

  1. Position: First moment / Center of area $(\bar{x}, \bar{y})$

     $\bar{x} = \frac{1}{A}\sum_{i=1}^{n}\sum_{j=1}^{m} i b_{ij}$, $\bar{y} = \frac{1}{A}\sum_{i=1}^{n}\sum_{j=1}^{m} j b_{ij}$

     where b_{ij} is the pixel value at row i and column j of the image

2. Orientation: Using axis of least second moment

$$Minimize\ inertia, E = a\ \sin^2\theta - b\ \sin\theta\cos\theta + c\ \cos^2\theta$$

where

$$a = \sum_{i=1}^{n}\sum_{j=1}^{m}(i-\bar{x})^2 b_{ij}$$
$$b = 2\sum_{i=1}^{n}\sum_{j=1}^{m}(i-\bar{x})(j-\bar{y}) b_{ij}$$
$$c = \sum_{i=1}^{n}\sum_{j=1}^{m}(j-\bar{y})^2 b_{ij}$$

are second moments with respect to center of area and

$$a' = \sum_{i=1}^{n}\sum_{j=1}^{m} i^2 b_{ij}$$
$$b' = 2\sum_{i=1}^{n}\sum_{j=1}^{m} ij b_{ij}$$
$$c' = \sum_{i=1}^{n}\sum_{j=1}^{m} j^2 b_{ij}$$

are second moments with respect to origin

Upon minimization, we get $\tan 2\theta = \frac{b}{a-c}$

We can use the ratio of $E_{min}\ and\ E_{max}$ to calculate roundedness of the object.