IMAGE MERGING ALGORITHMS USING PARTIALLY OVERLAPPED REGIONS

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Abstract. The optimization merging problem is formulated by the use common criteria of matching. Two algorithms are proposed, those give near optimal solutions. Three or four fragments matching is used instead of known algorithms to obtain good merging. The algorithms are included in the system of image processing of integrated circuit layers.

Introduction

The most of big images are an assembly of some picture areas. The neighboring picture areas have overlapping regions. That's way a combine of the partially overlapping images into one image is one of main element of image registration methods [1].

The main principle of the picture areas matching is based on correlation of the areas in the overlapping region. There are two approaches to extending correlation to include wider ranges of distortions. One method is to successively distort and correlate a reference template across a full range of distortions [2]. Classical technique of correlation and relaxation is used to find an initial set of matches, then a robust technique of the Least Median of Squares is used to discard false matches in this set. It is computationally very expensive. The algorithm calculates the squared difference per pixel of all possible overlaps between two adjacent images and selects the minimum. Using special transformations of initial images it is possible to speed up correlation.

Another approach is that of composite filtering, where a single filter responds to a full range of distortions [3]. Good technique for matching involves Fourier autocorrelation [4]. This technique replaces convolution-based template matching by Fourier transforming the source and template images, multiplying one by the complex conjugate of the other, then inverse Fourier transforming the result. The result should ideally provide a single peak at the single point of correlation.

Widely a method is used when for matching some overlap regions those are smaller, than the real matching region should be, are used [5-6]. For our application it is difficult to produce a good match.

For each of this approaches it is possible to use parallel matching algorithm to performance of calculation process. First some adjacent images select. Then, it iterates over all possible overlaps of these images. For each iteration, it calculates (in parallel) the sum of the differences between each pixel in the overlapping regions.

The main attention is paid t o strategies for finding near-optimal matching algorithms. They are very important to reduce a computational complexity of matching. In [8] the following search order was proposed. The search starts with the image in the lower-left corner of the matrix. It adds this image to the used frames set. From here it finds the image closest to the lower-left image that does not exist in the used frames set and enters a loop over all possible ranges of x and y motion (these ranges are user-selectable). At every possible shift of the image, it calculates the overlap area with each of the images in the used frame set and, if this area exists, calculates the root mean squared correlation error in the overlap region. If the error is less than the current minimum, the position is noted and the minimum value is updated. In this way, the minimum correlation of the image against all overlapping, previously matched images is determined. Once the entire range is evaluated, that image is moved to the position yielding the minimum correlation and it is added to the list of used frames. The process then repeats with the next image and continues until all images have been matched.

We discuss a merging problem in following two applications: wafer production and printed circuit boards inspection. The images are calibrated i.e. with known intrinsic parameters (have the same value of pixels). They are only rectangle images, there are no rotations, that's way any overlapping areas are rectangles too. The images have taken by a single camera but at different time instants or different light. There are some misplacements due to effect of perspective distortion or blurring occurs when object is out of focus on boundaries or object is vary in height.

Here we describe algorithms those allow to reduce a time complexity of merging. The optimization merging problem is formulated by the use common criteria of matching. Two algorithms are proposed, those give us near optimal solutions for frames merging. Three or four fragments matching is used instead of known algorithms to obtain good maching.

1. The problem definition

We can state the merging problem as follows.

The initial data for the picture areas matching are:

The matrix $[m_i^j]$ of the picture areas of dimension n x n.

The undirected adjacency graph of the picture areas G = (N,R) were 2 areas are only vertical or horizontal adjacent. N = { $n_{i,j}$, $i=\overline{1...n}$, $j=\overline{1...n}$ } is the set of the graph nodes. R = { r_i, $i=1,2,...,2(n-1)n$ } is the set the branches.

Sg and Sv are the sizes of overlapping regions.

Δg, Δv are the possible horizontal and vertical deviation of the overlapping regions.

The similarity criterion of two picture areas $P_{i,j}$ and $P_{k,l}$ is the discrete function f(h,v,$P_{i,j}$,$P_{k,l}$), were (i,j) and (k,l) are the indexes of the pictures that overlapping regions are matched, $k=i+1$, $l=j+1$, h and v are in range 0, 1, …, 2Δ.

Let the goal function $g=\sum_{i=1}^{n-1}\sum_{j=1}^{n-1} f(h,v,P_{i,j},P_{k,l})$ is defined.

The task is to find the optimal pictures coordinates that value of the function g is minimal.

The trivial solution is the full search of all possible combinations of the overlapping. This is not acceptable because of big amount of the combinations $(2\Delta)^{2(n^2-1)}$. From this pint of view the algorithms that realize the restricted search are the best solution.

Two ways of the picture areas matching are considered. The first way is use of the local matching quality criterion g' instead of g. The criterion g' calculates the matching quality of the partial matrix of the graph of the 2×2 size. The second uses the function g that has some restrictions, that allow reducing the search complexity.

The choice of the matching algorithms type depends on the quantity and characteristics of the errors that are added by input device. The algorithms are arranged according to the decreasing of the required accuracy of the input device.

2. The first merging algorithm

1. Lets define: on the vertical line the value V of the matching quadruples of the images if n mod 2 = 0 than V= n-2 else V = (n / 2)*2-2; on horizontal line the value H of the matching quadruples of the images if n mod 2 = 0 than H= n-1 else H = (n / 2)*2-1.

Lets initialize the absolute output coordinates.

2. For every quadruples of the images the actions are done:

Setting of the initial overlaps of images: i = 0, Sg,Sv;$\Delta gi = 0$, $\Delta vi = 0$, find the value f_0 of the function f, $f_{Opt} = f_0$., store the coordinates.

While the value f_{Opt} is decreasing make the shift of the images with the step equal 1. Store the coordinates.

Setting of the initial overlaps of images.

While the value f_{Opt} is decreasing make the shift of the images with the step equal -1. Store the coordinates.

In the given algorithm the quadruples order search is not described. The order have strong affect on the quality of the images matching.

3. The second merging algorithm

Lets define the discrete function $d_i(x, y)$ that is the distance function between the current position (x, y) of the i image and its optimal position regarding to the neighboring images that are fixed.

$$d_i(x,y) = \sum_{ki=1}^{K_i}(|x - OptX_{ki}| + |y - OptY_{ki}|),$$

where K_i is the number of the neighboring images of the i image, (x, y) are the current coordinates of the i image, $(OptX_{ki}, OptY_{ki})$ are the coordinates of the i image if the function $f(h,v,P_{i,j},P_{k,l})$ is maximal, where $P_{k,l}$ is the current ki neighbor image.

The second matching algorithm minimize the function:

$$g = \sum_{i=1}^{n^2} d_i(x,y) \to \min$$

,

where n^2 is the number of the graph nodes.

Thus there is the following matching algorithm:

1. At the initial stage the images are arranged that so overlapping regions have the sizes Sg for horizontal overlapping and Sv for vertical overlapping.
2. Setting the acceptable error lever *Err*.
3. While $\forall i, \max(d_i) > Err$, for every image make the shift $\vec{s}_i$, where

$$\vec{s}_i = \left(\sum_{ki=1}^{K_i}(x - OptX_{ki}), \sum_{ki=1}^{K_i}(y - OptY_{ki}) \right)$$

4. System of merging

The merging algorithms are included in the system of processing of layers of integrated circuits. The scenario of the system has the following steps:

1) Set up value of an average overlap of adjacent frames and value of the greatest possible vertical and horizontal deviation from an average overlap.

2) Set up a distance function of overlapped frames and a type of searching for matching algorithm (in columns, in rows, block-by-block with the different search schemes

using first or second type of matching algorithm).

3) The matrices are created for each of overlapping pare of frames. By criterion of distance minimum the optimal position is found.

4) The traversal of positioned frames is fulfilled according to matching algorithm and search scheme. After a positioning of all frames, a maximal vector of all produced moving which value is displayed in the main dialog window in current value monitor group is found. The matching is produced repeatedly so long as vector of maximal moving does not become equal to 0 or smaller then user determinates value.

Conclusion

Our algorithms have the following advantage in application to processing of digital video images of topological layouts of an integrated circuit represented as a set of overlapped frames: there are no complex computation needed to perform the mapping. Our experimental results demonstrate the possibility of automatically identifying adjacent positions by maching frames of ICs layouts.

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