# EE 645 - Course Project Phase - II
# Content Aware Rotation

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## Brief overview

To perform Content Aware Rotation, the authors warp the image by optimizing a quad mesh by imposing constraints that preserves the lines, shapes and boundary. Also, there is an additional constraint on rotation that is manipulated by rotating a few lines more rigidly than the others by imposing penalties. The crux of the entire paper is to be able to model various constraints in terms of an energy optimization function, which is solved by various numerical techniques finally.

## Energy Function

The energy function has four major components, $E_S(V), E_B(V), E_L(V,\theta),$ and $E_R(\theta)$, corresponding to the shape preservation energy, boundary preservation energy, line preservation energy and rotation manipulation energy. The variables $V$ and $\theta$ are respectively vectors that consist of the list of all final coordinates of the warped mesh and the angle by which the quantized bins must be rotated. The overall energy is given by,

$$E(V,\theta) = E_S(V) + \lambda_B E_B(V) + \lambda_L E_L(V,\theta) + \lambda_R E_R(\theta),$$

where $\lambda_B, \lambda_R$ and $\lambda_B$ were set experimentally to $100, 100,$ and $10^8$. The individual energy functions are,

$$E_S(V) = \frac{1}{N}\sum_q ||(A_q(A_q^T A_q)^{-1}A_q^T - I)V_q||^2$$

$$E_B(V) = \sum_{i\in \text{Left}} x_i^2 + \sum_{i\in \text{ Right Boundary}} (x_i - w)^2 + \sum_{i\in\text{Top}} y_i^2 + \sum_{i\in\text{Bottom Boundary}} (y_i - h)^2$$

$$E_L(V,\theta) = \frac{1}{K}\sum_k ||(R_k U_k R_k^T - I)e_k||^2$$

$$E_R(\theta) = \sum_m \delta_m(\theta_m - \Delta)^2 + \sum_m (\theta_m - \theta_{m+1})^2$$

Here, the authors have proposed an alternating algorithm where they optimize $E(V,\theta)$, first with respect to $V$ and then with respect to $\theta$.

## Progress thus far

I have so far completed up to step (2) of the methodology. Firstly, using open CV's inbuilt line segment detector, I have detected all the line segments. After detecting them, I quantize all of them and put them into bins, where I compute the initial orientation of each line as per the paper and allocate to each line a bin, where each bin is set to be rotation by different angles. I have also computed a grid consisting of 500 squares for the image, each of whose transformed coordinates make up the variable $V$. Also, I have computed each of the line id's with their corresponding bins, which will later be used in various other functions that I will be using.

## Issues Faced

The next step in this process is to optimize the energy function using the method given by the authors, but the equations as mentioned above are not exactly explicit about $V$ and $\theta$. They first fix $\theta$ and solve for $V$, and then fix $V$, solve for $\theta$. Because the first is a quadratic in $V$, once we fix $\theta$, this can be solved by forming a linear system. In the equation for line preservation, the authors have computed a matrix $P_k$, that multiplied by $V$ yields $e_k$. I have not been able to compute $P_k$ thus far. Similarly, for $E_S$, the authors leave it as $V_q$, which I have been able to decompose into two matrices, $Q$ and $V$, where $Q$ is a sparse matrix that I had to compute in order to be able to write the function in the form of a standard quadratic. I took the help of the TAs (Gagan) and Rajendra to find $Q$. I am currently working towards writing $e_k$ as $P_kV$ and also writing the energy function for the boundary in terms of $V$. Because of this the optimization function so far has not been solved, and thus I am not able to show the warped mesh, following which, using bilinear interpolation or by considering barycentric coordinates, I'll warp my image for each mesh. This issue was majorly due to my lack of knowledge on solving quadratic forms in linear algebra.

## Work from now on

The next phase of my project would involve me solving the first part of my optimization function, followed by the second part of the optimization function. As soon as I find the matrices $V_q$ and $P_k$, I will need to write it in terms of $x^TAx + c^Tx$, subject to some constraint depending on the input variables, and solve it via a linear equation. The part involving fix $V$, solve for $\theta$ has a *half-quadratic splitting technique*, where this problem is again broken down into two subproblems, on an auxillary variable $\phi$ and $\theta$, which again involves a lookup based method and a quadratic programming problem. This will be a part of my next phase of work. Also, I am currently using OpenCV's inbuilt function for Line Segment Detection. I'll be using a different Line Segment Detector for the final phase of my project; this was the one used in the original implementation of the paper.

## Conclusions

My project is more of a one shot project where once I solve the optimization function, I will get the results directly after warping. Because of the above issues faced, I haven't so far solved the optimization problem. The results after warping will be completed by Phase III of the project.

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## The initial proposal from phase 1 is attached here

## Significance

Usually, pictures that are not carefully taken have some kind of tilt associated with them. This can lead to them looking tilted and not straight. The methods that are usually adapted to resolve this issue of a tilted image is rotation and cropping. A very important shortcoming of a method like cropping would include loss in data, which in turn might adversely affect the integrity of the image. Yet another issue is that even for very small angles of rotation, roughly around $5^o$, there is a reduction in the area of a typical photo by roughly 20% [1]. Rotation being such an important component of image editing operations along with cropping and scaling has not had a lot of work trying to solve this fundamental problem described above.

Content Aware Rotation tries to solve this fundamentally important problem without cropping or scaling and uses a warping method to create the perception of rotation while keeping the image content inside a upright rectangle. This is motivated by human perception, which could very well be significant in other computer vision problems as the ultimate aim is to reach a level where we can match human level vision. Yet another significance of content aware rotation is that it is fast and can be used by common people.

## Objectives

The main objective of this project is to implement the paper on Content Aware Rotation and compare the results that are obtained with regular cropping and rigid rotation. For doing the same, the authors of the paper come up with an optimization based method that "preserves the rotation of horizontal/vertical lines, maintains the completeness of the image content, and reduces the warping distortion" [1]. A Quad Mesh is optimized for warping, under various constraint that a few lines preserve orientation and few don't. Warping methods are used because they can preserve local shapes and straight lines [5]. This objective shall be achieved by performing various steps as described in methodology.

## Methodology

- The algorithm to be described assumes that the angle of rotation of the input image is already given and that it is fixed or can be computed using an algorithm in [3].
- Firstly, there is line extraction and quantization that is done using [4]. Then the orientations of these lines are computed and the ones that are to preserve orientation are classified as canonical. These are identified by allocating to each line a bin, that is a measure of the orientation of the line. These canonical lines are in the canonical bins.
- An energy function is defined now, inspired from [5]. Various different constraints are imposed in this stage. These constraints cover the canonical lines, maintaining content completion by constraining the boundary vertexes and to minimize the local distortions so that shape is preserved. These are various factors that model the energy function. Each constrain to be modeled is an energy function in itself and the overall energy function is defined to be a linear combination of all of these. The aim is to minimize the *overall* energy function, which is a

function of the vertexes of the mesh grid and a quantity obtained by using the rotation angle of the input image.

- Optimization of the Energy Function: The authors propose an alternating algorithm. They optimize the energy by dividing the problem into two subproblems and then iteratively optimize each of the subproblems.
- Finally, Bilinear interpolation is done to deform the image to get the final image.

## Expected Outcomes

- The rotated image after applying the algorithm is the expected output. This method performs well for small angles of rotation, which is usually the case for regular images.
- There will be comparisons that show where all Content Aware Rotation does well and where all it doesn't and a suitable reasoning for the same.
- The limitations of the method. For an instance it cannot do very well in a setup where there are too few operations that can be performed without getting noticed. Whenever rotation angle is large, it might have the above issue. These are in general the expected outcomes of Content Aware Rotation.

## References


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