The eroding rotation: Why digital pictures should not be rotated

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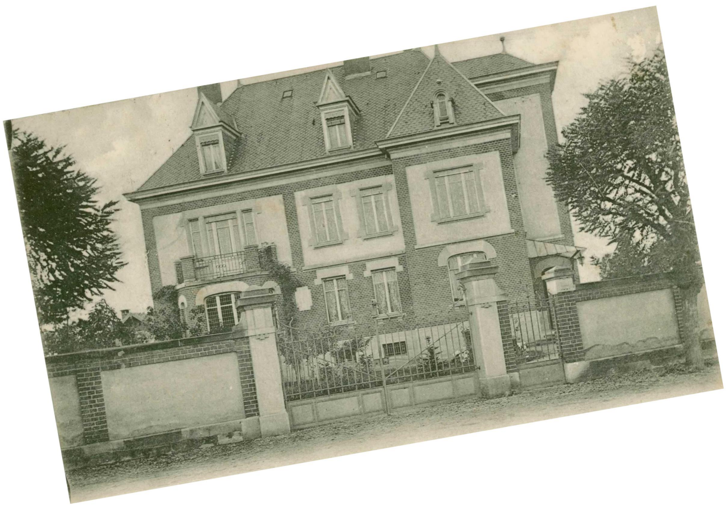
Digital pictures are now ubiquitous and they are produced through a variety of sources: scanners, digital cameras, cell phones, web cams, screenshots, to name a few. Some of these pictures end up being published, which means that in most cases they will be printed.

But published pictures must conform to a certain standard of quality, and for a number of reasons, in particular æsthetic ones, lines are rendered as they are expected to be rendered. A photograph of some landscape, for instance, will normally be shown with the real horizon being horizontal. This seems totally obvious, but in fact it doesn't have to be so. It is just more convenient, and the photograph then becomes a natural extension of the observer.

Unfortunately, some of the pictures aimed for publication are not perfectly ready to be shown. This is for instance the case for the photograph shown below:



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In practice, the defects of real pictures are not as important as in the previous example, but the author of a publication may feel a need to slightly rotate the pictures he is displaying, especially if these pictures exhibit straight lines, like in the above example. A number of subjects are not as sensitive to rotation and cropping a picture can be a quite acceptable way to hide a digital anomaly.

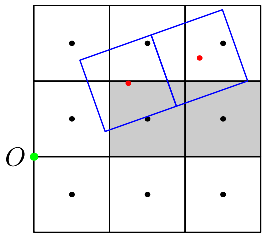
When however a picture has to be rotated, the effects can be more far reaching than the short-term publication. In fact, the picture may have been an archival picture, and it is then likely that this archival picture will also end up being rotated. This seems a quite benign operation, some adjustment of a very different nature than color adjustments. After all, isn't a digital rotation just like a physical rotation? Isn't it as simple as moving the picture with our fingers? It turns out that it isn't as simple. In fact, in most cases, rotating a digital picture damages it[1].

The reason for this damage is quite simple. Most of the pictures are bitmaps, which are arrays of square pixels. These pixels are transferred on screen or paper, where similar arrays are present. One pixel of the original picture may correspond to one pixel on paper, but more likely there will be some conversion, some kind of conversion ratio. The pixels of the picture will be aligned with horizontal and vertical lines, and so will be the pixels on paper. Therefore, if a picture needs to be rotated, its pixels will first be abstractly rotated, but again fitted to another horizontal/vertical grid. In addition, pixels are not just black or white, but they can have some value in between, and these values only belong to a finite set. If you imagine one very large black pixel, and a slight rotation of this pixel around its lower left corner, some parts of the original pixel will cover other pixels, and the darkness of these other pixels may have to be changed. If the value of a pixel is only 0 or 1, then there will be some threshhold and some pixels will move, while others will not, depending where they are located. These transformations will slowly erode the picture, because some information gets lost. The process is normally not reversible. Although this loss is only very small, it should be avoided, if possible, especially by people who are holders of digital archives.

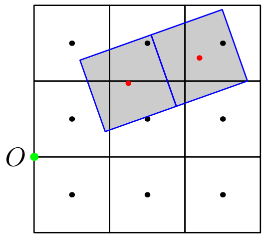
An example will make this clear. Consider the following fragment of an image, where we have two dark pixels (in gray). The pixel centers are shown, and we rotate the image around point O by 19.5 degrees. The two rotated

[1] A number of web sites seem to contradict this statement, for instance the pages about "lossless JPEG rotation," but these sites concern another kind of damage, such as a loss of resolution when cropping a picture, or the loss resulting from accumulated compression/decompression, and usually only rotations of multiples of 90 degrees are considered. This is different from the problem examined here, which is inherent to the bitmap representation of images.

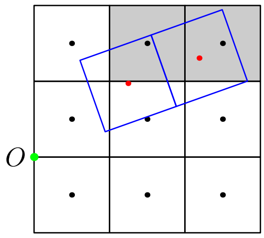
pixels are shown as an overlay, as well as their centers.



The following picture shows these rotated pixels, but they do not fit the initial grid.

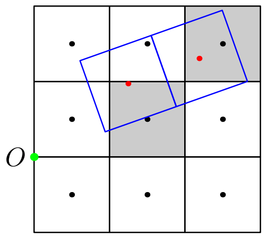


In this case, a pixel being either black or white, we must choose which pixel gets altered. This is not as simple as it seems, and we can imagine different solutions. We can for instance darken the pixels which are covered by more than a half of their surface by black pixels.



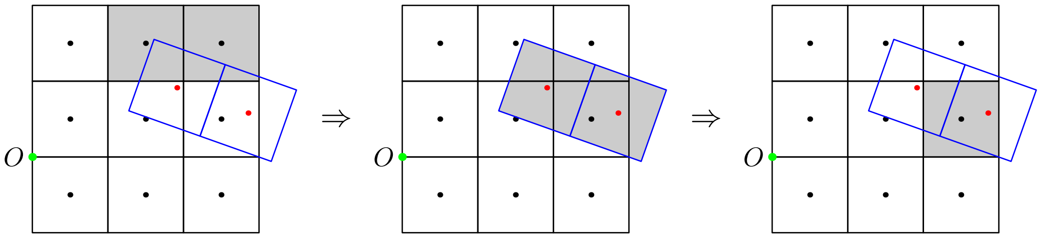
(global approach)

Another solution is to consider individually each rotated pixel, and to check where its center is located, and darken the corresponding pixel. This does not give the same result:

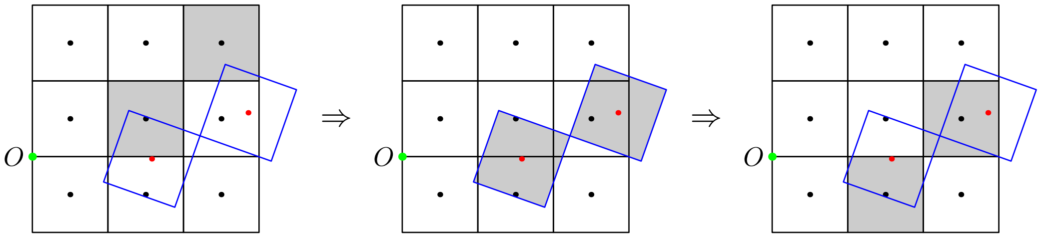


(local approach)

If we choose the global approach, and perform the inverse rotation, applying the same criteria, we end up with only one dark pixel, because the pixel in the middle has less than half of its surface covered by a rotated black pixel:

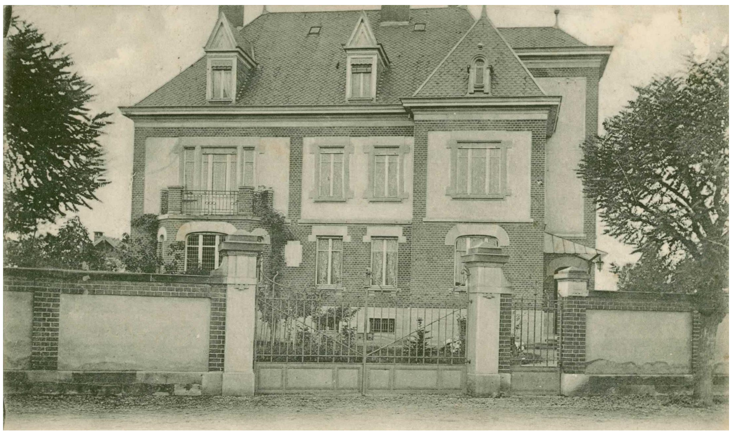


If, on the other hand, we choose the local approach, we end up with another result, also different from the original configuration:



This simple example has shown that performing one rotation in one direction, followed by the same rotation in the opposite direction can result in either pixel losses, or pixel displacements. There are of course cases where the pixels are not altered, but in the above cases only one pixel out of the two dark ones has returned in its correct position. This should be convincing enough of the non-anecdotical nature of the image erosion.

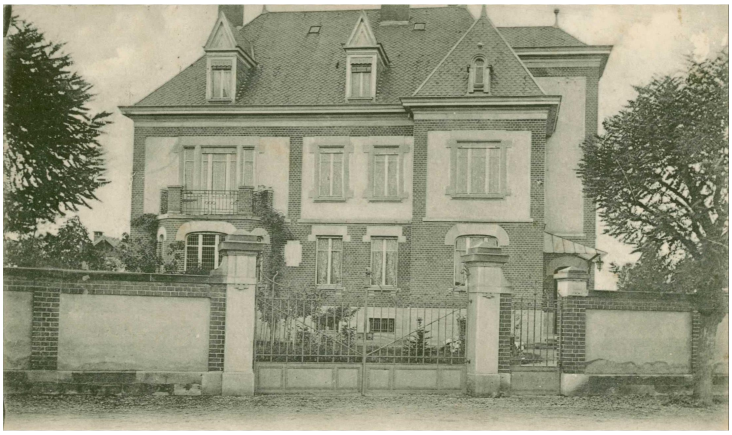
Now, in order to make this loss more explicit, we consider again the initial picture, this time in its original orientation:



Original picture

We are going to apply a simple transformation to this picture, namely, rotate it counterclockwise by one degree, and then again by one degree clockwise[2]. The result is:

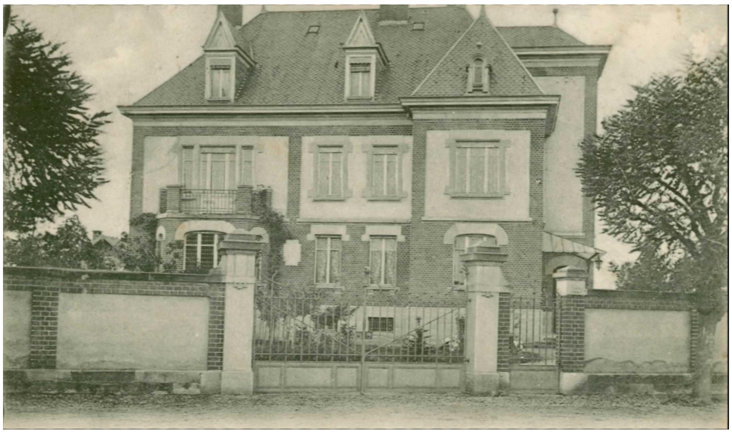
[2]All the rotations were performed using the `pnmrotate` program on the Linux operating system.



Original picture rotated by $1 - 1$ degrees.

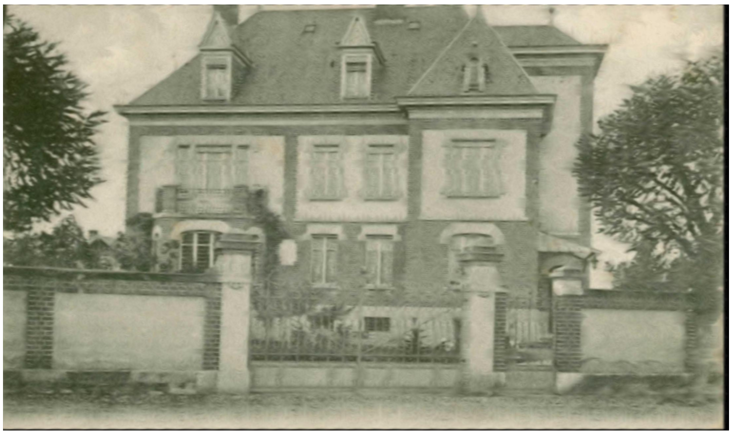
Although the two pictures are already slightly different, this is practically impossible to notice. However, the erosion has started, and the disease is there, only at its first stage.

We now speed up the erosion, and add four more steps:



Original picture rotated by $5 \times (1 - 1)$ degrees.

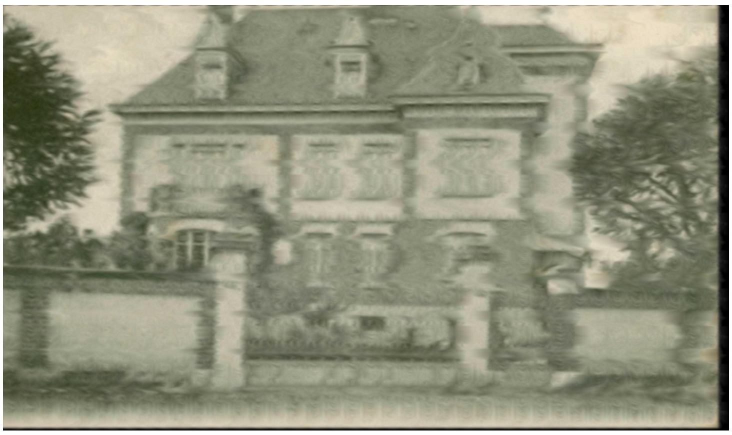
The picture still seems quite acceptable, but the disease has made progress. We now add 15 steps:



Original picture rotated by $20 \times (1 - 1)$ degrees.

We can now see the first signs of the damage. Although some parts are still acceptable, the overall feeling is that the picture is no longer as sharp as the previous one, but the greatest damage seems to have taken place for the upper windows, whose frames now seem to undulate.

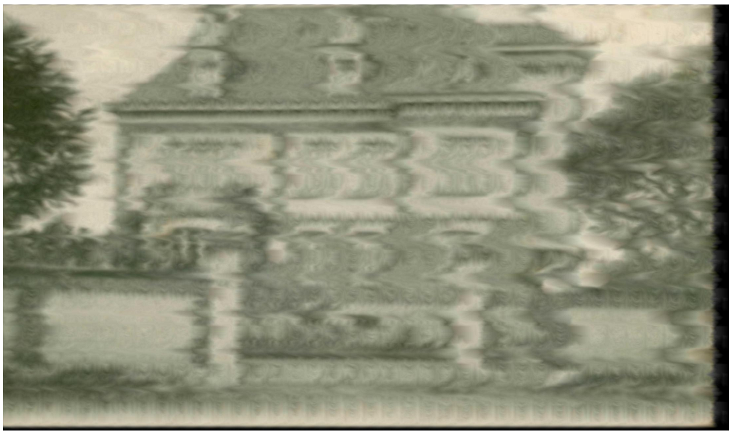
We can still go further. Twenty steps later, we reach this picture:



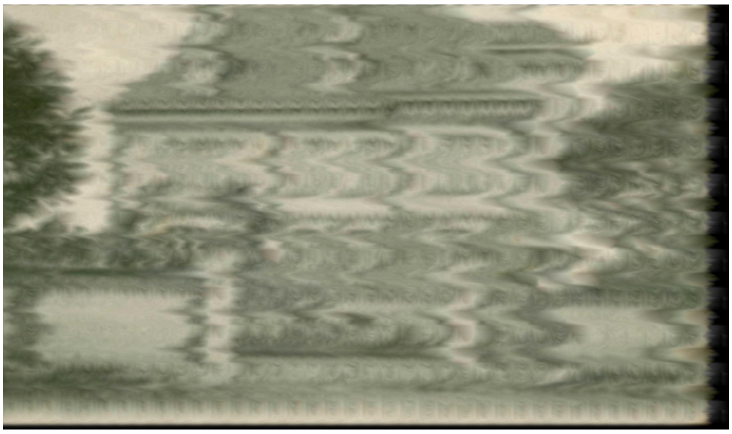
Original picture rotated by $40 \times (1 - 1)$ degrees.

The damage has increased, but the house can still be recognized, as well as the trees. Incidentally, the black line on the right is an artefact of our rounding process. There is a slight drift, and this drift is made apparent because we ensure that the picture always has the same pixel size after the two elementary rotations.

We could iterate this process many times, but we are just showing two more positions, after a total of 60, and a total of 80 elementary $1 - 1$ steps:



Original picture rotated by $60 \times (1 - 1)$ degrees.



Original picture rotated by $80 \times (1 - 1)$ degrees.

This last picture seems in very bad shape, but it is only 80 times the damage which was made to the first picture. The harm was done at the beginning.

The conclusion is: do not rotate bitmap pictures, because most of the time you will damage them! Instead, try to produce high quality pictures right away, if you can, and be sure to store the best pictures you have and protect them from the harm of rotation. It takes more time to produce good pictures at the beginning (for instance by scanning), but you will save time in the future, because you will not have to go through such a process again.

For L. B. and her Archives.