PROJECT 1 REPORT

Quantitative Results:
For problem 5, our program generates nine images. These are the result of applying each filter to each type of noise. Here were our results:

```
[out1.jpg]   MEAN       filter over   UNIFORM    noise   ERROR: 902.561552
[out2.jpg]   MEAN       filter over   GAUSSIAN   noise   ERROR: 821.988159
[out3.jpg]   MEAN       filter over   S & P      noise   ERROR: 822.568310
[out4.jpg]   GAUSSIAN   filter over   UNIFORM    noise   ERROR: 1185.954853
[out5.jpg]   GAUSSIAN   filter over   GAUSSIAN   noise   ERROR: 1106.185038
[out6.jpg]   GAUSSIAN   filter over   S & P      noise   ERROR: 1106.577982
[out7.jpg]   MEDIAN     filter over   UNIFORM    noise   ERROR: 888.653904
[out8.jpg]   MEDIAN     filter over   GAUSSIAN   noise   ERROR: 823.110408
[out9.jpg]   MEDIAN     filter over   S & P      noise   ERROR: 822.640810
```

Just from looking at the numbers, it appears that the Gaussian filter is the least effective, as the error between the filtered and unfiltered images appears to be significantly greater than the error for the other two filters. This, of course, is based on the assumption that a greater error between input and output images indicates a less effective filter. When looking at the actual images, though, this assumption doesn't hold true, as the Gaussian filter *appears* to do a decent job filtering background noise. The winning filter, however, is the median filter.

Qualitative Results:
It appears that there is no filter that fixes every type of noise. Let's look at the results on a by-filter basis. For the mean and median filters, a kernel size of 5x5 was used. For the Gaussian filter, a sigma of 1.8 was used, resulting in a 5x5 kernel. An image reference for all nine comparisons is attached to this document.

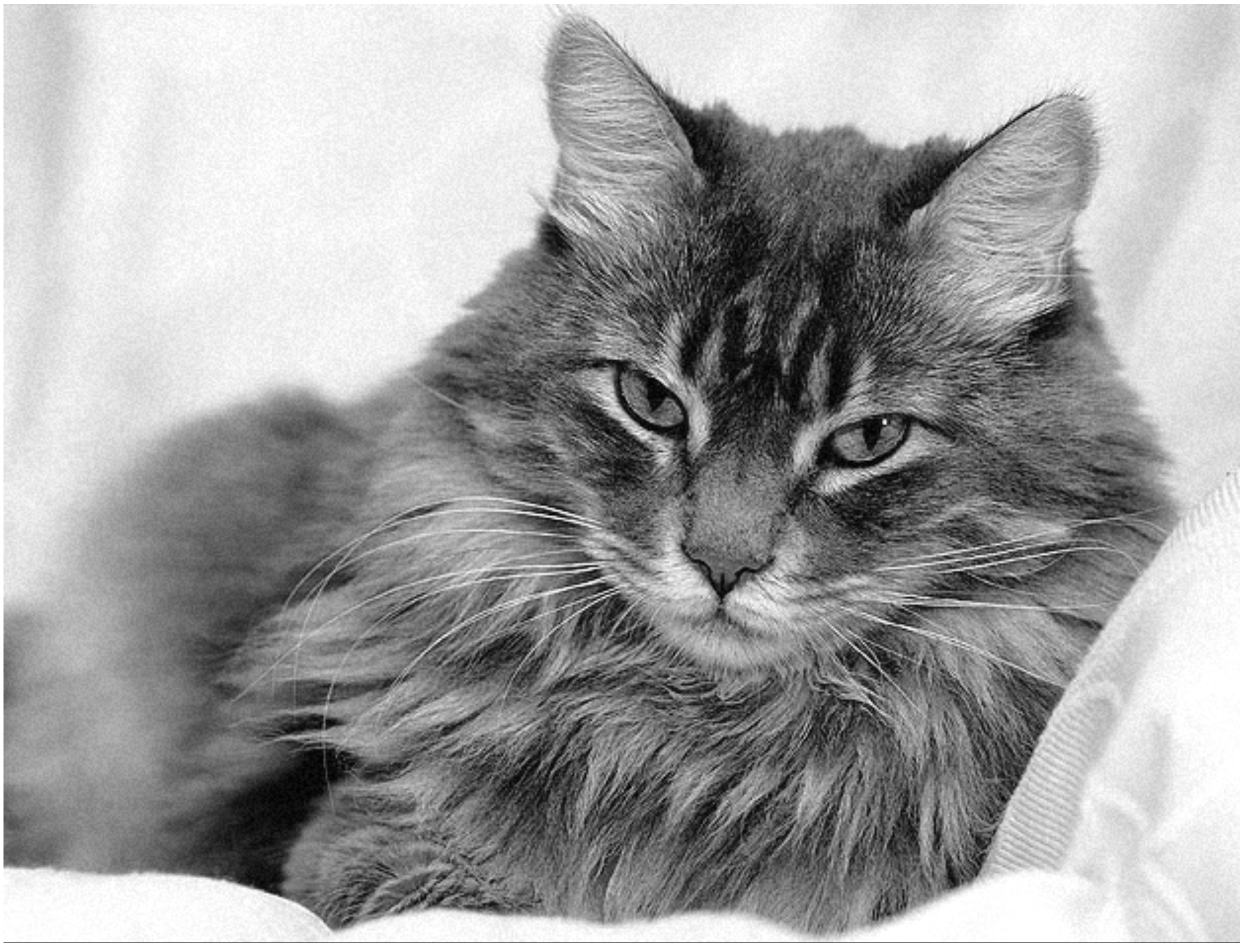
The **mean filter** did a decent job of removing uniform background noise, and better so for Gaussian noise. Luckily for my cat images, no "squaring" artifacts appeared that are common among mean filters. The mean filter, however, was no match for the salt and pepper noise. While the salt (white pixels) seemed to filter out very well, the pepper (black pixels) turned into square, grey blobs against the bright background. So, provided the salt and pepper is surrounded by either a consistently similar area OR a varied area, the mean filter takes care of S&P noise somewhat well.

The **Gaussian filter** performed slightly better than the mean filter. Over uniform noise, it appeared to blur slightly better than the mean filter. It did an excellent job of blurring our Gaussian noise in the background, although the cat in the foreground (who wasn't affected by noise in the first place) became significantly blurred. And while a better performer than the mean filter, the Gaussian filter fleshed out the salt and pepper noise as well. The filter suffers from the same fault as the mean filter in that pixels surrounded by a high contrast area are still greatly noticeable. The salt and pepper still appear as squares, albeit feathered more on the edges.

Finally, the **median filter** performed very well over Gaussian and S&P noise. It effectively blurred peppers on the white background, essentially erasing them from the image. This holds true for the thinly-speckled Gaussian noise as well. Over the uniform noise, however, the median filter did not perform well. While it effectively reduced the sharpness between noise in the background, it managed to decrease the resolution of the noise itself; grey pixels that were once tiny appear as much larger, albeit blurry, squares. In highly detailed, variable areas, such as the actual cat's face, the median filter tended to reduce the variations in intensity throughout, turning a once vibrant image into a series of homogenous clumps.

So for smaller kernels over Gaussian and S&P noise, the median filter shines. It tends to blend background pixels very well while preserving some of the original image's sharpness. The Gaussian filter, over uniform and Gaussian noise, can perform well if the right sigma/kernel size is chosen (an ideal one blurs the background only to the point that the foreground does not noticeably suffer). Despite the mean filter's relatively low error, it performed the worst out of the three, despite quick performance and relatively low error.

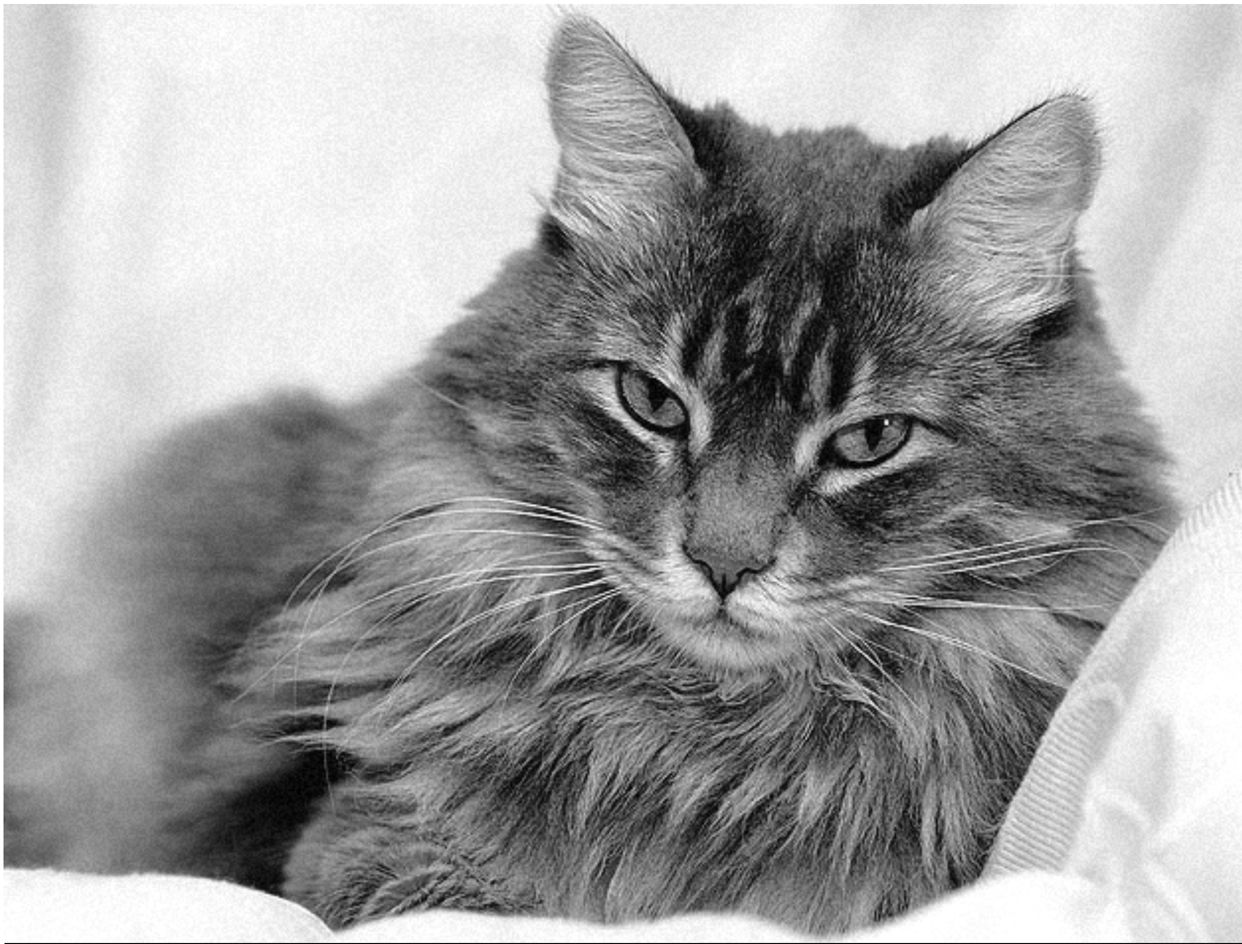
MEAN filter over **UNIFORM** noise



MEAN filter over **GAUSSIAN** noise

MEAN filter over **SALT & PEPPER** noise

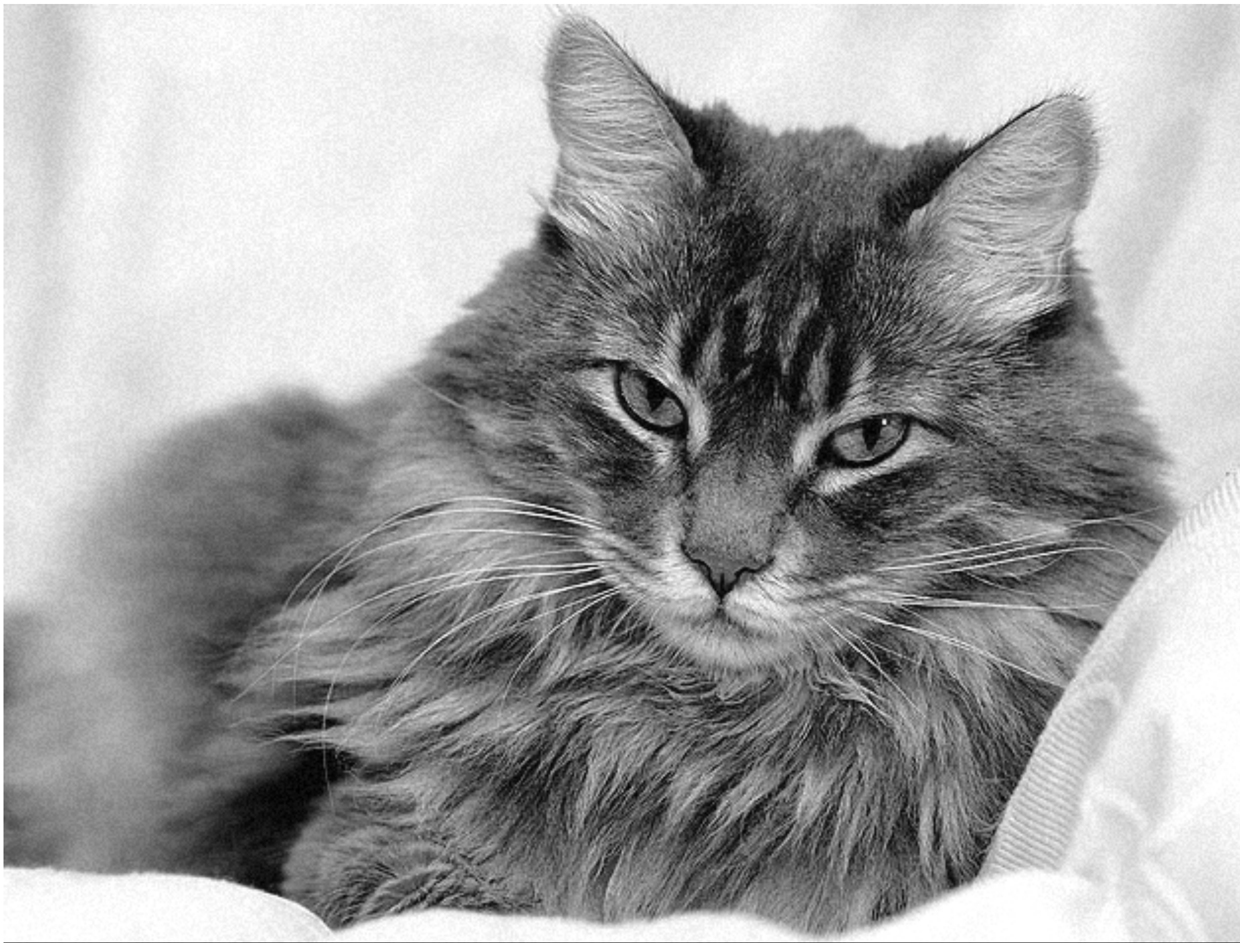
GAUSSIAN filter with **UNIFORM** noise



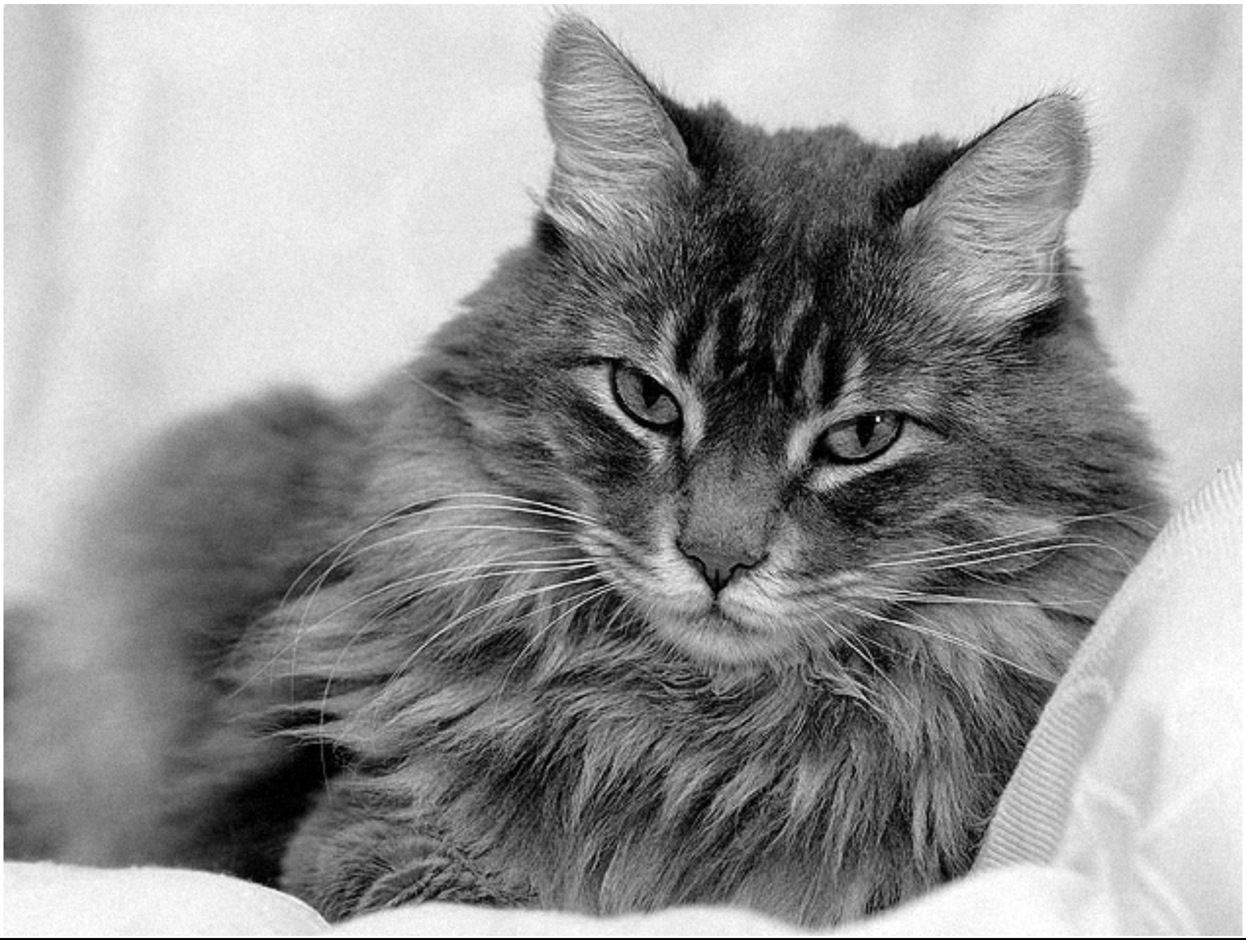
GAUSSIAN filter over **GAUSSIAN** noise

GAUSSIAN filter over **SALT & PEPPER** noise

MEDIAN filter over **UNIFORM** noise



MEDIAN filter over **GAUSSIAN** noise



MEDIAN filter over **SALT & PEPPER** noise