CT Image Enhancement for ICH Classification

World ICH conference 2017, Baltimore

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Disclosures

- This project is funded through a research grant from the National University of Malaysia (GGMP-2015-033)
- My co-affiliation: University of Nottingham, UK

Outline

- Introduction
- Methods
- Results
- Discussion

Introduction

- Spontaneous intracerebral haemorrhage- affects older people
- 2 most common causes:
  - Hypertension
  - Cerebral amyloid angiopathy
- Clinical symptoms often identical

Introduction

- Diagnosis of CAA is important:
  - risk of recurrence higher in CAA
  - avoid antiplatelet/ anticoagulant?

Introduction

- Diagnosis of CAA mainly based on MRI

Radiological features	Hypertensive ICH	CAA-related ICH	Modality
Location	Deep seated	Superficial cortical	CT &MRI
Cerebral microbleeds	Deep seated, pontine	Cortical-subcortical junction	MRI
Superficial siderosis	-	+	MRI

- Shortcomings:
  - availability of MRI is limited
  - longer scan time
  - patient may not be stable
  - contraindications to MRI

Aims

- To identify the best enhancement techniques in CT images for ICH classification.
- Improve the yield of CT scan in differentiating hypertensive vs CAA-ICH.

METHODS

Image Processing Techniques

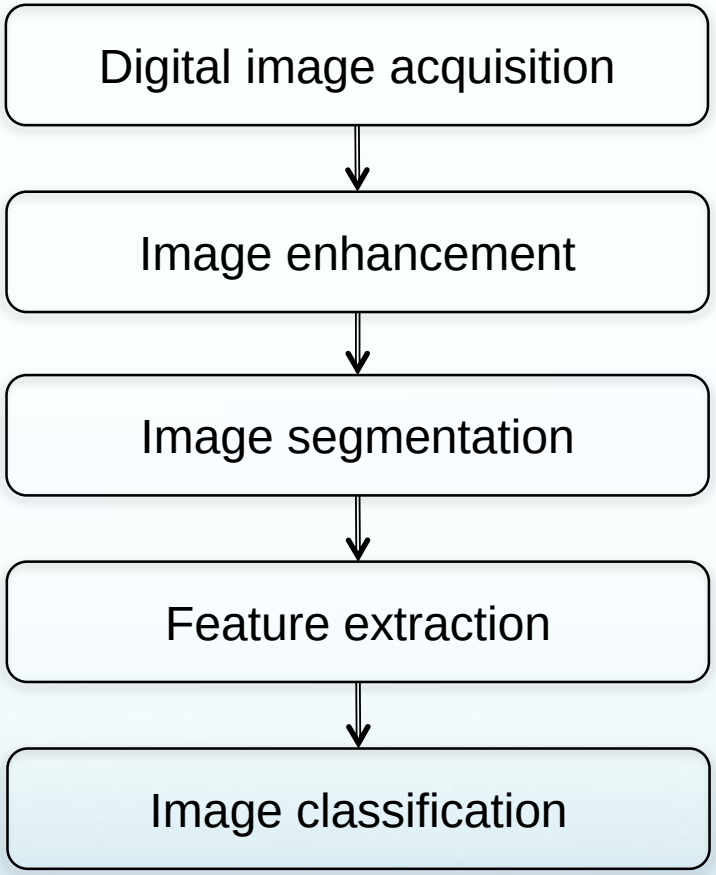
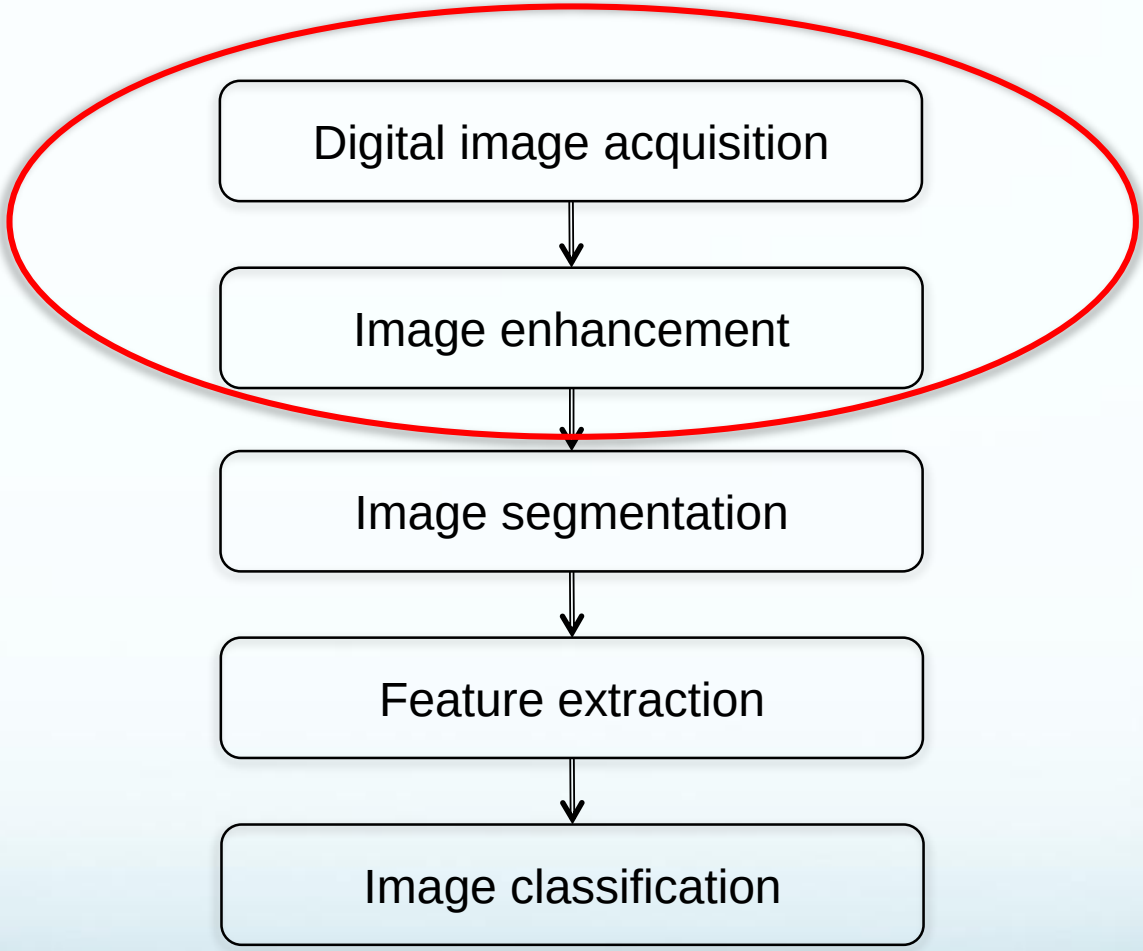


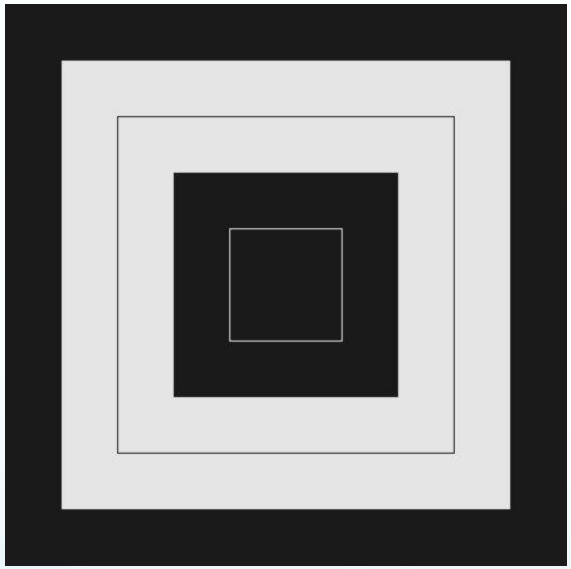
Image Processing Techniques



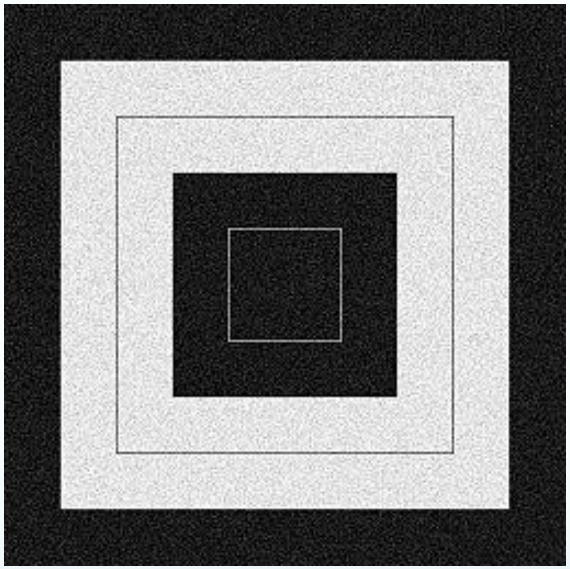
Methods

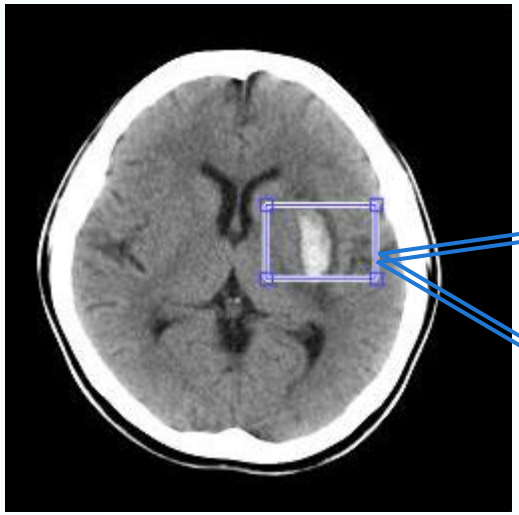
- Enhancement of CT images
- Improve the quality (clarity) of images by :
  - Removing noise
  - Brightening the image by increasing contrast and revealing key details required for further processing
- Blur affects the visualization of small objects
- Noise affects the visualization of low contrast objects

No noise



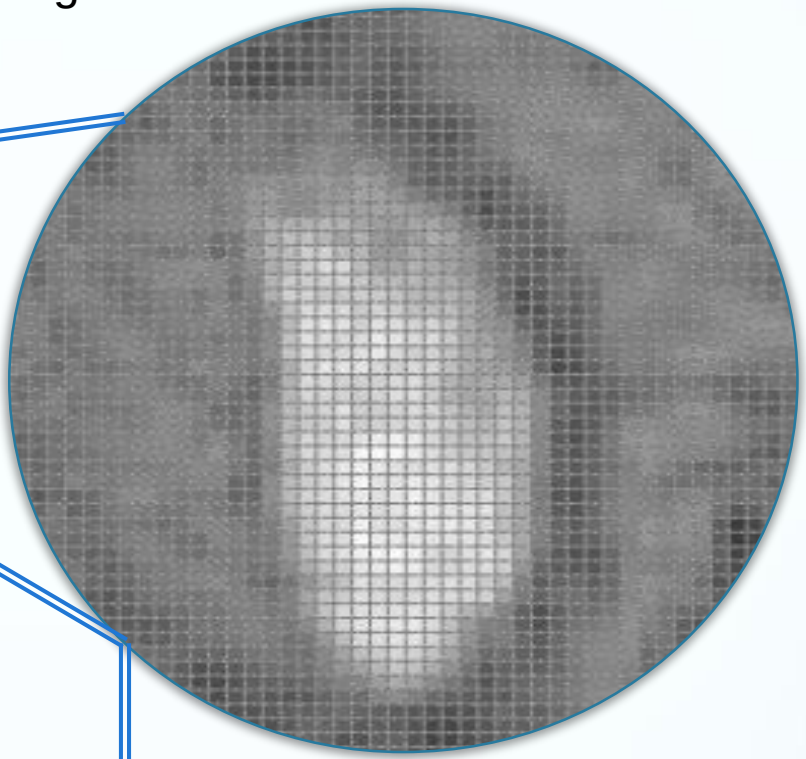
With Noise





Gray scale brain image

Pixel region of bleed



R:213 G:213 B:213	R:213 G:213 B:213	R:212 G:212 B:212	R:205 G:205 B:205	R:211 G:211 B:211	R:221 G:221 B:221
R:204 G:204 B:204	R:211 G:211 B:211	R:226 G:226 B:226	R:206 G:206 B:206	R:207 G:207 B:207	R:212 G:212 B:212
R:201 G:201 B:201	R:207 G:207 B:207	R:224 G:224 B:224	R:206 G:206 B:206	R:208 G:208 B:208	R:214 G:214 B:214
R:212 G:212 B:212	R:211 G:211 B:211	R:216 G:216 B:216	R:226 G:226 B:226	R:234 G:234 B:234	R:240 G:240 B:240
R:216 G:216 B:216	R:219 G:219 B:219	R:221 G:221 B:221	R:245 G:245 B:245	R:249 G:249 B:249	R:248 G:248 B:248

Pixel values of bleed

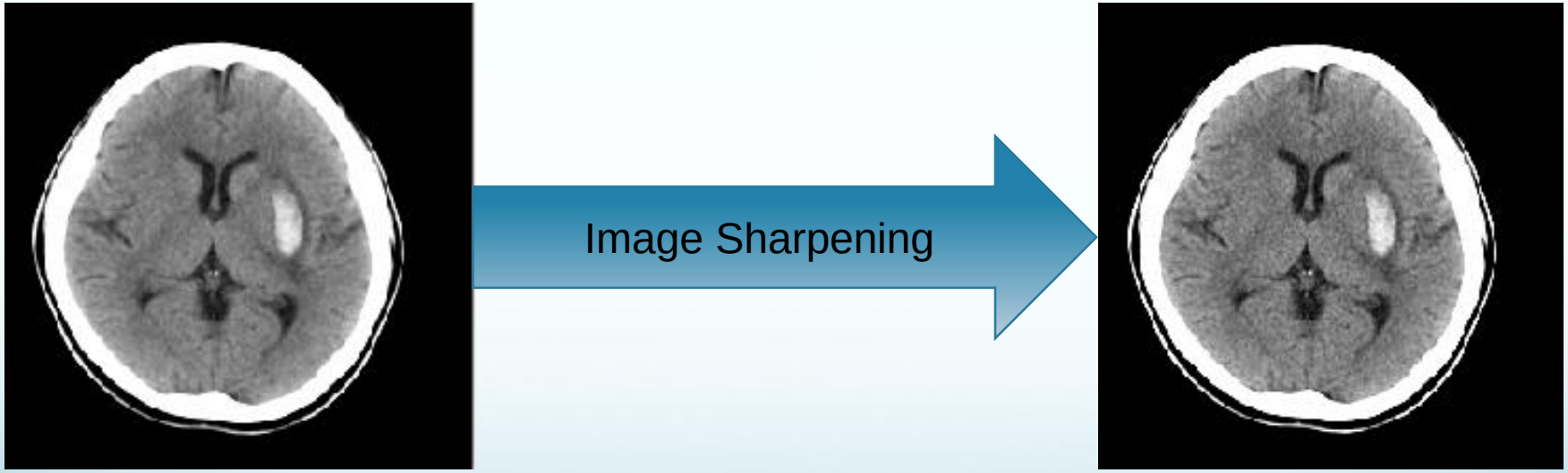
Enhancement= manipulation of pixel values

Methods

- 3 different enhancement techniques, utilizing MATLAB software:
  - sharpening using unsharp masking,
  - adaptive histogram equalization and
  - median filter

Methods

Types of enhancement techniques	Concept / Definition	Advantages
Image Sharpening	Helps in highlighting edges and removing blurriness from the image.	It increases the intensity of image in darker regions than in lighter ones.

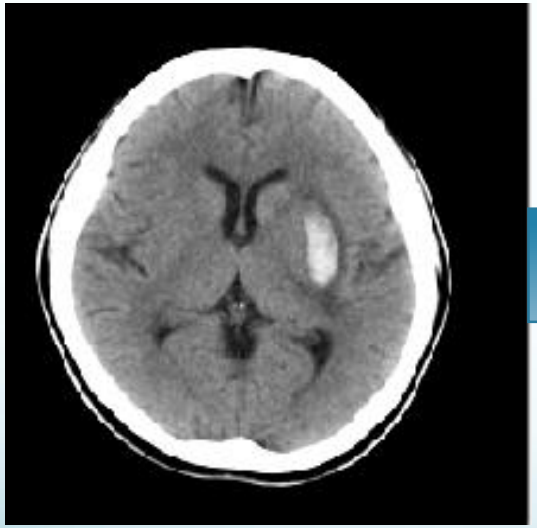


Input image
(Original gray scale image)

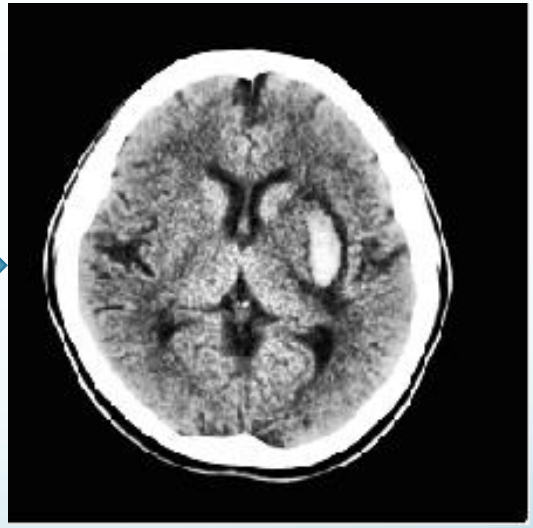
Output image
(Processed image)

Methods

Types of enhancement techniques	Concept / Definition	Advantages
Adaptive Histogram Equalization	Operates on a smaller local region of an image rather than the global region.	It has the capability to enhance the subtle changes in the image for further processing.



Adaptive Histogram Equalization

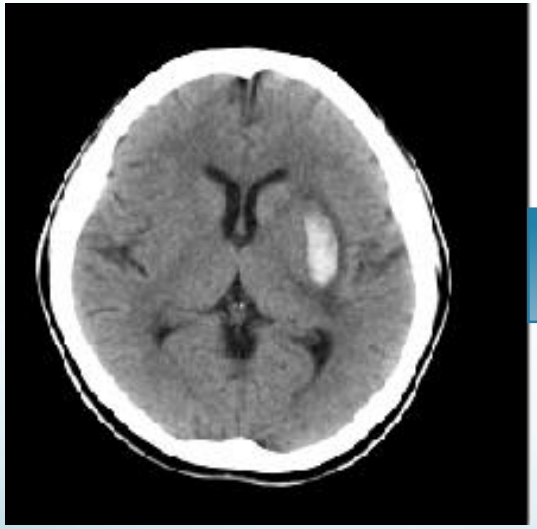


Input image
(Original gray scale image)

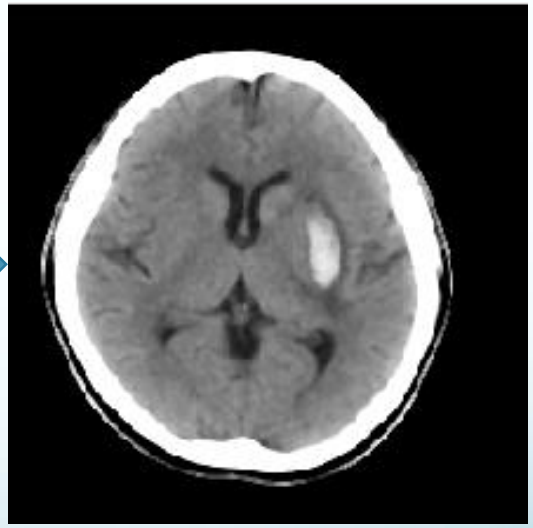
Output image
(Processed image)

Methods

Types of enhancement techniques	Concept / Definition	Advantages
Median Filter	Used to remove ‘salt and pepper’ noise.	Preserves the edge of the original image and does not shift the boundaries of the image.



Median filter



Input image
(Original gray scale image)

Output image
(Processed image)

Methods

- Comparisons of the techniques were done in two categories:
  - C1, CT **including skull**, of normal and ICH patients were compared with
  - C2, **skull stripped** CT of normal and ICH patients
- The performance analysis of the images:
  - Blur: absolute mean brightness error (AMBE) and entropy values.
  - Noise: *Root Mean Square Error (RMSE)* & *Structural Similarity Index (SSIM)*

Performance analysis

- *Absolute Mean Brightness Error (AMBE)*
  - Difference of brightness between original and processed image
- *Entropy*
  - Measures the richness of information contained in the image after enhancement techniques have been applied

The nearer AMBE and entropy to the original values the better since less data of the images are lost after being processed.

Performance analysis-noise removal

- *Root Mean Square Error (RMSE)*
  - Measures the differences between the processed and original image.
- *Structural Similarity Index (SSIM)*
  - Measures the similarities between the processed and original image.

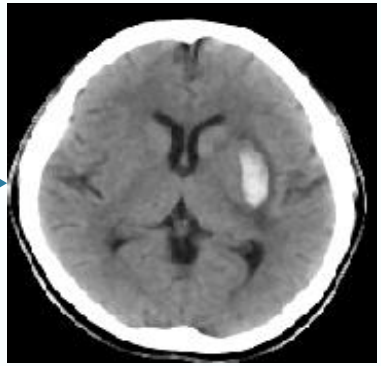
Both RMSE and SSIM compare processed CT image against MRI image which would have less noise (gold standard)

Example :

Gray scale brain image

1	3	7	9	8
4	10	5	18	20
13	17	16	3	15
25	11	23	22	9
2	7	15	1	16

Pixel values of gray scale image



Processed brain image using technique 1

10	3	13	9	11
4	5	17	18	20
13	17	16	3	15
25	11	25	22	9
2	7	15	1	16

Pixel values of processed image with low entropy

Processed brain image using technique 2

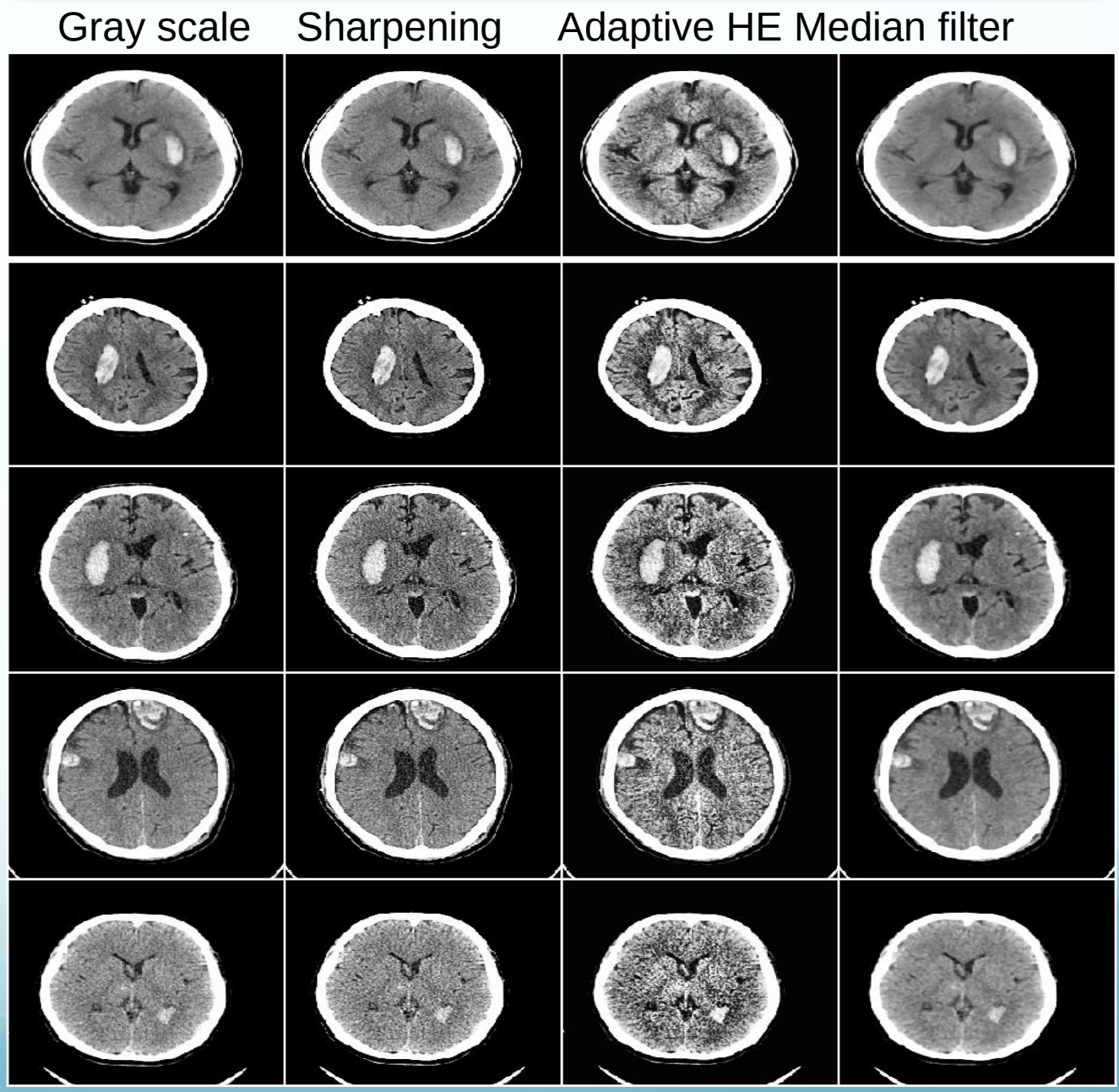
50	50	50	50	50
50	25	17	25	50
50	25	50	25	50
50	50	50	50	50
50	25	50	25	50

Pixel values of processed image with high entropy

RESULTS

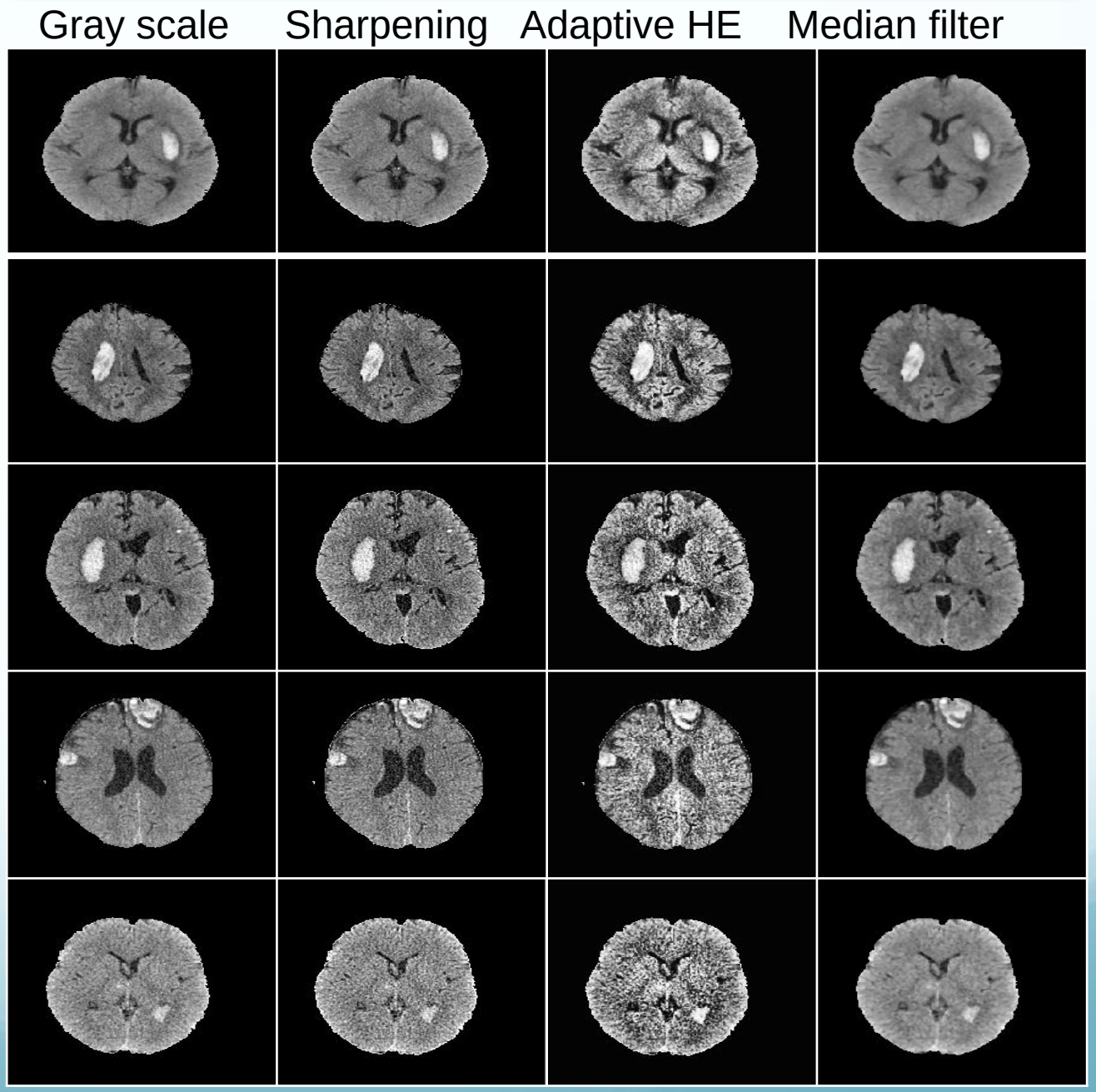
RESULTS : CATEGORY 1

Figure 1 : ICH CT images with skull of 5 patients



RESULTS : CATEGORY 2

Figure 2 : ICH CT images without skull of 5 patients



RESULTS: Table I

TABLE I. Performance analysis for CT images with skull (C1) for all 5 samples

Samples / Image Enhancement Techniques	CT images of pICH patients with skull							
	AMBE				Entropy			
	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter
Sample 1	0	4.86	0.01	0.38	4.14	4.47	4.06	4.13
Sample 2	0	5.62	0.15	0.10	2.77	2.95	2.76	2.70
Sample 3	0	5.29	0.12	0.42	4.24	4.47	4.21	4.16
Sample 4	0	5.50	0.03	0.25	4.01	4.26	3.98	3.92
Sample 5	0	0.66	0.03	0.11	3.68	3.95	3.67	3.59
Average	**0**	**4.39**	**0.07**	**0.25**	**3.77**	**4.02**	**3.74**	**3.70**

RESULTS: Table II

TABLE II. Performance analysis for CT images without skull (C2) for all 5 samples

Samples / Image Enhancement Techniques	CT images of pICH patients without skull							
	AMBE				Entropy			
	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter
Sample 1	0	6.02	0.45	0.09	3.34	3.68	3.41	3.30
Sample 2	0	6.11	0.24	0.09	2.28	2.48	2.34	2.23
Sample 3	0	6.23	0.50	0.21	3.58	3.85	3.64	3.49
Sample 4	0	6.21	0.31	0.28	3.24	3.51	3.32	3.15
Sample 5	0	0.07	0.22	0.23	3.08	3.35	3.15	2.97
Average	**0**	**4.93**	**0.34**	**0.18**	**3.10**	**3.39**	**3.17**	**3.03**

RESULTS: Table III

TABLE III. Measuring level of noise in an image for C1

Samples / Image Enhancement Techniques	CT images of pICH patients with skull							
	RMSE				SSIM			
	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter
Sample 1	0	17.96	5.74	7.83	1.0	0.6	1.0	1.0
Sample 2	0	16.60	5.52	5.92	1.0	0.6	1.0	0.9
Sample 3	0	20.91	8.49	12.31	1.0	0.6	1.0	0.9
Sample 4	0	19.60	7.54	8.66	1.0	0.6	1.0	0.9
Sample 5	0	19.23	7.13	8.90	1.0	0.6	1.0	0.9
Average	**0**	**16.86**	**6.88**	**8.72**	**1.0**	**0.6**	**1.0**	**0.92**

RESULTS: Table IV

TABLE III. Measuring level of noise in an image for C2

Samples / Image Enhancement Techniques	CT images of pICH patients without skull							
	RMSE				SSIM			
	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter	Original gray scale value	Adaptive Histogram equalization	Image sharpening	Median filter
Sample 1	0	18.20	5.26	6.58	1.0	0.5	1.0	1.0
Sample 2	0	17.00	5.18	6.97	1.0	0.5	1.0	0.9
Sample 3	0	21.32	8.35	11.41	1.0	0.6	1.0	0.9
Sample 4	0	19.65	6.63	8.57	1.0	0.5	1.0	0.9
Sample 5	0	19.04	6.58	10.18	1.0	0.5	1.0	0.9
Average	**0**	**19.04**	**6.40**	**8.74**	**1.0**	**0.52**	**1.0**	**0.92**

Conclusion

Image sharpening using the unsharp masking outperforms the adaptive histogram equalization and median filter for images with and without skull in C1 and C2.

Discussion

- CT without skull C2- better noise reduction
- Image sharpening preserves the brightness and richness of the images as well as reducing the Gaussian noise present in CT images.

Next steps

- Semi-automated segmentation of haematoma
- Feature extraction: microbleeds? Not seen on unprocessed CT image
- On another 40 patients
- ICH classification based on processed validated by MRI image

THANK YOU
Questions and answers

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