Tremor Quantification Methods

① Statistical Analysis of Pixel Placement

↳ Analysis of patterns in tremor diag...

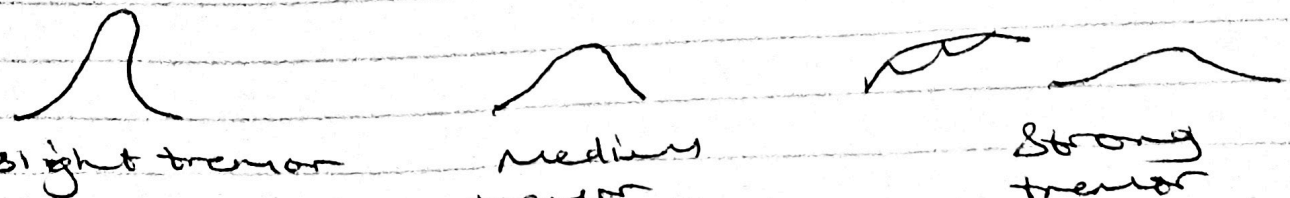
- Patient draws spiral
- Spiral area is digitalized and drawing extracted
- Using Sobel filter for horizontal and vertical direction the gradient and it's orientation ϕ are computed for every foreground image pixel I_f

$$\phi(x,y) = \arctan\left(\frac{\nabla_y I_f(x,y)}{\nabla_x I_f(x,y)}\right)$$

- The angle α between each pixel and the image centre (centre of spiral) relative to a horizontal line through the centre is calculated
- The relative orientation θ of all lines a is found using

$$\theta = \phi - \alpha$$

- Relative orientation of all lines is used to calculate the mean and standard deviation.
- Visualised using a histogram



~~Stats~~ → Application of machine learning and numerical analysis ...

② Statistical Analysis in Polar FORM

- Determine the coefficient of offset (α) for the printed spiral

$$\theta = \alpha r \qquad (1)$$

- compare traced & data points to the printed data points in (1) and linearize using:

$$r = \sqrt{(x-x_0)^2 + (y-y_0)^2}$$

↳ r and θ derived from x and y coordinates recorded from pen

- θ calculated using:

$$\theta = \tan\left(\frac{y-y_0}{x-x_0}\right), \quad x_0 \text{ and } y_0 \text{ are spiral centre coordinates}$$

↳ θ is a series of increasing or decreasing positive or negative values depending on Cartesian quadrant.

- tremor score calculated by determining:
  - Maximum difference between the radius of the printed spiral and the tracing radius Δr_{max}.
  - average radius difference between the printed spiral and the tracing radius: Δr_{avg}.
  - the square of the Pearson product moment correlation coefficient for tracing r and θ data points: R^2.
  - the RMS of the radius difference
  - the standard deviation σ of the radius difference between printed spiral and tracing.

In what way do these vals depend on tremor and not just dev from template

- These values were used to decide on final tremor rating score.

↳ Quantification of tremor with a dig

(3) Area Under Tremor Peaks

- x and y tremor amplitudes were computed by taking the square root of the area under the x and y spectral peaks
- the overall tremor amp was calculated by taking the square root of the sum of the areas under the x and y spectral peaks.

* How do we automatically determine where the spectral peaks are?

4. Using Spires for Statistical Analysis

Quantification of the drawing of an Archimedes spiral
through the analysis of its digitized picture

1. Spiral specimens were digitalized at a resolution of 650×650 pixels and the images were salved to a 24-bits bitmap file. Then, bitmap files were decodified and displayed in an 8-bits graphic screen.
2. Pixels that represented the spiral drawn by the subject were selected thanks to its different colours (red versus black—colour of the print template or white—background colour) and their *x*, *y* co-ordinates were saved to an ASCII file.
3. The origin of the co-ordinates axis (0, 0) was the centre of the model spiral.
4. The spiral was then reconstructed (i.e. *x*, *y* spiral pixels co-ordinates were ordained following the temporal sequence in which they were drawn by the subject) through a semi-automatic procedure.
5. The pixels were first classified by spires. This was accomplished representing spiral pixels on the computer screen according to the angle that they form with the *x*-axis (range from 0◦ to 360◦) and the distance from the origin (i.e. polar co-ordinates or radius-angle transformation, Pullman, 1998). This allowed to a human operator to delimit the limits of each spire and then the computer classified the pixels accordingly.
6. Once the computer determined the spire to which it pertained, it was possible to calculate for each spiral pixel the difference between its distance from the origin and the distance of the corresponding model spiral point (i.e. the point of the model situated at the same spire and angle that a given spiral pixel).
7. Finally, spirals were reconstructed beginning with the pixel pertaining to the first spire and forming the lowest angle with the *x*-axis. Subsequent pixels were selected in basis to its proximity with the last pixel orderly. At the end, a set of *m* pairs of *x*, *y* co-ordinates values $\{(Xs, Ys)\} = \{(Xs_0, Ys_0), (Xs_1, Ys_1), \ldots, (Xs_{m-1}, Ys_{m-1})\}$ were obtained.
8. Analysis of spiral specimens was performed in three different ways. Firstly, the cross correlation coefficient (Ks,m) between the subject spiral picture and the model spiral picture (Gonzalez and Woods, 1992) was calculated.
9. Secondly, the mean (REmean) and standard deviation (RES.D.) of the radial error was calculated.
10. Finally, the transformed spiral {(Xt_, Yt_)} was spectrally analysed by means of the FFT.