Can you trust your EEG-device?
Robust EEG quality control requires automatization.

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Purpose

A simultaneous activation of thousands of neurons on the brain cortex produces a measurable electric field near the brain extending up to the scalp. This can be recorded using an electroencephalogram (EEG) or an intracranial EEG device. Typical EEG signal amplitude varies between 1 to 100 µV with frequency between 0.5 to 100 Hz. However, during an epileptic seizure the signal can get up to the amplitude of 1 mV and the frequency of 250 Hz [1]. The recording of a signal with these ranges requires an adequate EEG amplifier [2, 3], which in turn requires a robust and objective quality control (QC) protocol to ensure reliable EEG studies. However, analysing the recorded EEG data can become highly time consuming and error-prone if it is done manually.

In this work a Matlab (*The MathWorks Inc., Natick, MA*) program, *EEGQC*, which was written to address these practical analysing problems is presented for the first time. The main graphical user interface of the program is shown in Figure 1. Results of the program were compared with results gained by analysing the same data manually. The accuracy, the precision and time consumption of the analysis was considered in the comparison.

Methods

An example in-house QC protocol was used in this study [4]. It consisted of a noise measurement and seven different signal measurements. The first three signals used 5 Hz constant frequency and amplitudes of 100 µV, 50 µV and 25 µV. The last four signals used 1 mV constant amplitude and frequencies of 5.0 Hz, 20 Hz, 50 Hz, and 70 Hz.

Six similar EEG devices (*Nervus device, Cephalon Ltd., Nørresundby, Denmark*) were measured using the example QC protocol in three consecutive years. All devices had an amplifier with 24 EEG channels and 8 bipolar channels. Signals were measured as peak-to-peak voltages (V_{pp}) from a local minimum to a local maximum to avoid errors arising from shifts in the baseline. It was estimated that to achieve precise and repeatable results, over 1000 measurement points would be needed in manual analyses for each EEG device. Hence, a compromise between the accuracy and time consumption of the task was made and measurement points were collected with the best judgement of the technician. The *EEGQC* program searched the largest and the smallest V_{pp} values within each selected time interval by using a moving temporal window with chosen width and a step size of one second.

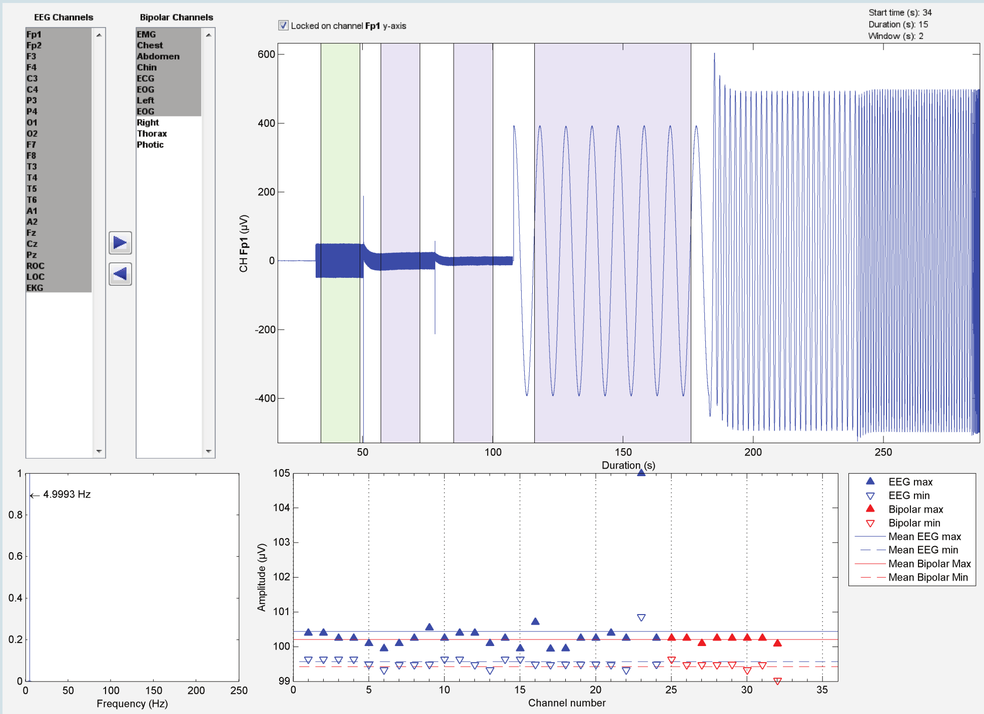

Figure 1. *The graphical user interface of the EEGQC program consists of four parts. The first part has two list boxes, one for EEG channels and one for bipolar channels. Only selected channels (grey) are used in analysis. The second part is the main axes next to list boxes. It is used to view signals from different channels and to select the position and the length of the time intervals and sizes of temporal windows within them. Specifications of an active window (green area in the main axes) can be seen in the top right corner. The third part in the left bottom corner shows a fast Fourier transform of the signal in the active time interval. The fourth part summarizes local minima and maxima found in the active time interval.*

Results

An average of 18 measured V_{pp}-values for each of used signals and the noise measurement were calculated. The relations between average and generated signal amplitude were collected in Table 1 with the averages of noise measurements. The first four signal measurements and the noise measurement showed a significant difference between manually gathered results and the results gained from the program. Only in two cases out of eight a significant positive correlation between manual and automated measurements was found. All 18 analyses were completed in less than seven hours using the *EEGQC* program.

Measurement		Relation to generator signal		p-value	Correlation	
Amplitude	Frequency	Manual	Program		R-value	p-value
25 µV	5 Hz	4,30 %	15,60 %	<0,05	0,33	0,09
50 µV	5 Hz	2,10 %	10,40 %	<0,05	-0,21	-
100 µV	5 Hz	0,20 %	2,30 %	<0,05	-0,30	-
1 mV	5 Hz	-1,30 %	-0,70 %	<0,05	-0,09	-
1 mV	20 Hz	-4,50 %	-1,20 %	0,72	0,88	<0,05
1 mV	50 Hz	-8,90 %	-8,10 %	0,09	0,36	0,07
1 mV	70 Hz	-19 %	-1,60 %	0,76	0,91	<0,05
Noise		1,79 µV	3,25 µV	<0,05	0,18	0,25

Table 1. *Results are shown as the relative difference between the generated signal and the average result of signal measurements. The noise result is a plain average of measurements. Linear correlations between manual and program results were calculated as well as the significance of correlations.*

Conclusion

The lack of correlation between the manual and automated results implies that a technician will not be able to provide reliable results if the time available for the analysis is not sufficient. In the case of automated analysis, the given time frame in a hospital environment will not be an issue. In addition, using an automated program, results will be objective and reproducible. Based on these results, it is recommended to use automatization in the EEG quality control.

References

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