SPEM - BASED ASSESSMENT OF SUPRASEGMENTAL EFFECTS OF SELECTIVE POSTERIOR RHIZOTOMY

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Abstract: The paper describes a method for analyzing an oculographic record to quantify the quality of smooth pursuit eye movements. Change in the quality of pursuit movements is one of the suprasegmental effects of selective posterior rhizotomy, which is performed in cerebral palsy patients affected by severe spasticity.

Introduction

The selective posterior rhizotomy is performed in cerebral palsy patients affected by severe spasticity [1]. One of the suprasegmental effects of this operation (such as improvement of speech fluency, lower spasticity in upper limbs, reduction of congenital nystagmus, changes in cortical response to the transcranial magnetic stimulation) can also be change in quality of smooth pursuit eye movements (SPEM).

To examine smooth pursuit eye movements, they are measured by a video-oculographic system when a sinus stimulus is usually used.

It means that a position of both eyes is recorded when the subject is observing a moving target whose speed is changing according to the sine curve. This stimulation can be performed horizontally or vertically.

All data presented on this paper ware taken using the horizontal stimulation.

In case of non-patient subjects, the eye response corresponds very well to the stimulation. See Figure 1.

Traditional way how to quantify the eye response is to fit a sine curve on it and to compare this curve with the stimulus evaluating parameters such as gain ratio, phase shift, frequency shift and direct current component.

Unfortunately, in case of subjects affected by severe spasticity the eye response is often very low correlated to the sinus signal and the parameters mentioned above can't be evaluated.

Objective is to quantify eye responses of spastic subjects before and after the selective posterior rhizotomy to support a research of University Hospital Motol, Department of Pediatric Neurosurgery, Prague, Czech Republic.

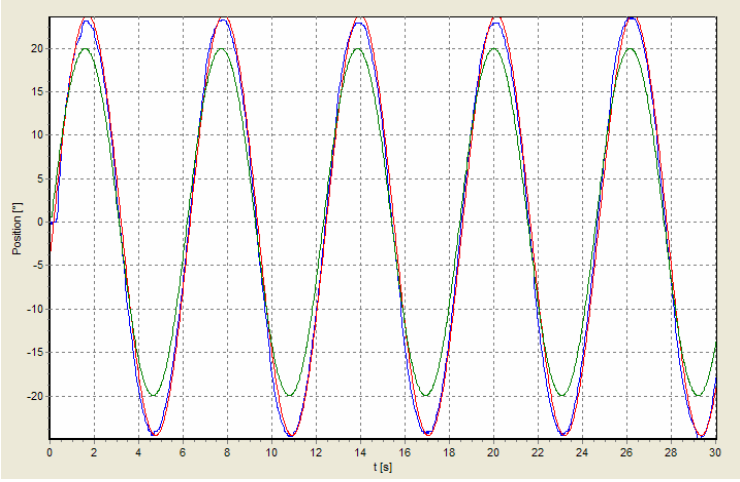

Figure 1: SPEM record measured on non-patient subject. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Green line: target signal. Blue line: eye response signal. Red line: sine curve fitted on eye response.

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Methods

The method how to assess the quality of recorded eye response that is roughly non-ideal is based on the following idea: Since we expect the sinus eye response, we can estimate an ideal sinus model of the eye response signal that has the lowest possible mean square error from this signal.

Then, we can evaluate the correlation coefficient between this model and the eye response. The lower the mean square error is and the higher the correlation coefficient is, the better can be the eye response replaced with the ideal sinus model and the better actually is.

Next parameters that can also be assessed are the correlation coefficient and the mean square error between the eye response and the target trace.

The model is estimated by a genetic algorithm that optimizes all of the sine curve parameters - amplitude, frequency, phase shift and mean value (direct current component) - minimizing the mean square error form the eye response signal until it is no longer improving. The genetic algorithm works with the population of size 20 using rank fitness scaling, stochastic uniform selection function and scattered crossover.

Using this setting, the result is no longer improving after approximately 500 generations and the process takes about two minutes.

Results

There are data measured on four subjects before the selective posterior rhizotomy has been performed presented in Table1, and after the SPR has been performed in Table 2. There ware two records measured on subject 1 available.

The correlation coefficient and the mean square error values are calculated for the sinus model and for the target trace.

Table 1: Data taken before the selective posterior rhizotomy has been performed.

subject	correlation coeff. [-]	mean square error [°]	correlation coeff. [-]	mean square error [°]
1a	0.544	95.35	0.530	95.35
1b	0.380	87.70	0.291	98.10
2	0.357	176.70	-0.028	338.20
3	0.389	429.84	0.305	576.23
4	0.962	43.60	0.958	131.00
	eye response – sinus model		eye response – target trace	

Table 2: Data taken after the selective posterior rhizotomy has been performed.

subject	correlation coeff. [-]	mean square error [°]	correlation coeff. [-]	mean square error [°]
1a	0.764	35.83	0.595	57.70
1b	0.713	14.90	0.699	43.78
2	0.447	86.60	0.339	214.30
3	0.379	130.07	0.353	139.72
4	0.985	6.88	0.987	8.32
	eye response – sinus model		eye response – target trace	

The following figures (Figure 2-11) show a graphical representation of measured eye responses and estimated models for each subject. The blue line always represents the eye response and the red line represents the best sinus model that can be fitted on this eye response.

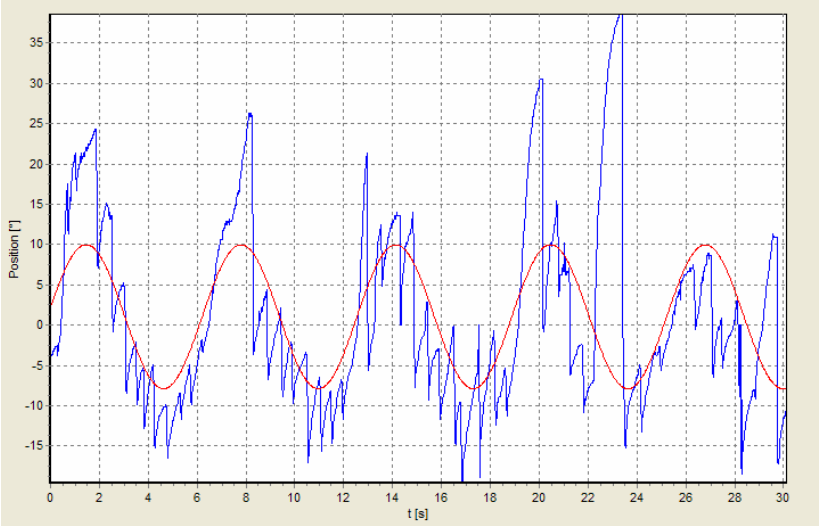

Figure 2: SPEM record measured on subject 1 before SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

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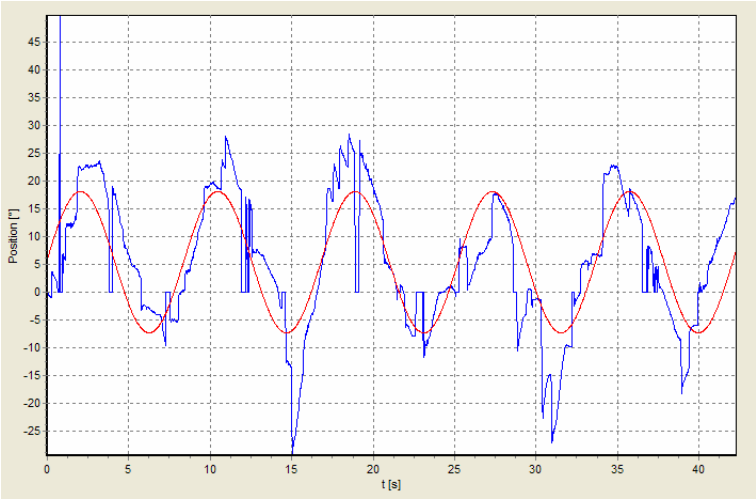

Figure 3: SPEM record measured on subject 1 after SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

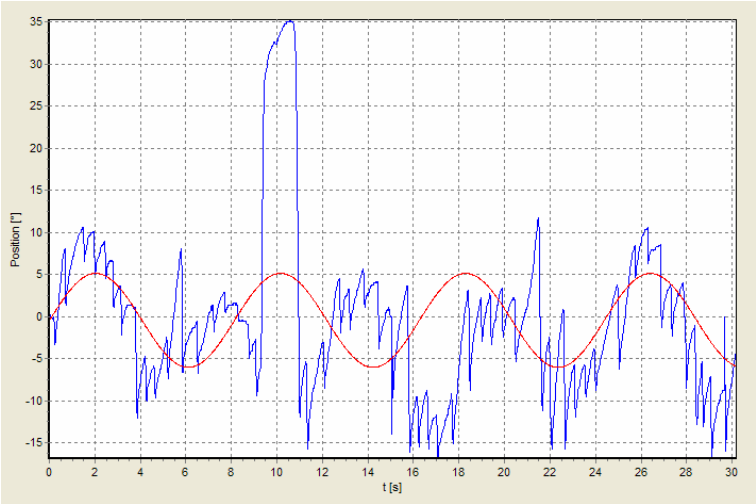

Figure 4: SPEM record measured on subject 1 before SPR – second record. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

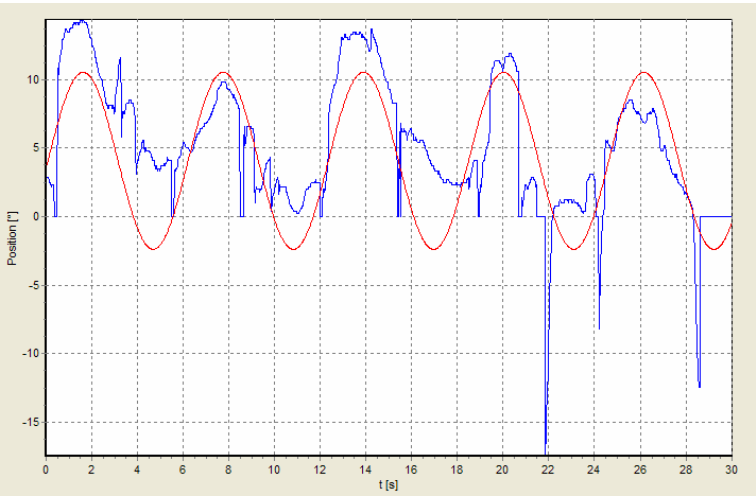

Figure 5: SPEM record measured on subject 1 after SPR – second record X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

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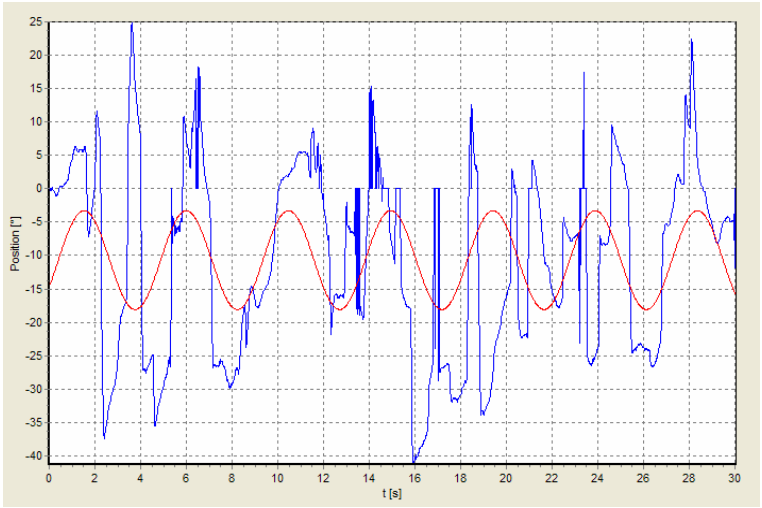

Figure 6: SPEM record measured on subject 2 before SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

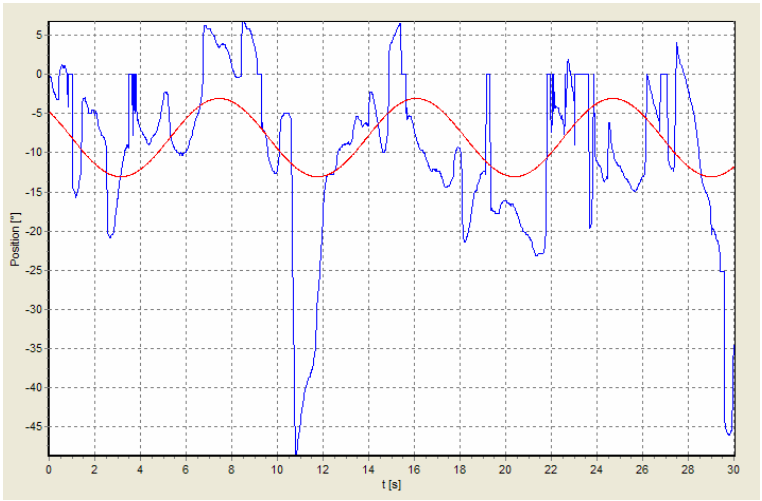

Figure 7: SPEM record measured on subject 2 after SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

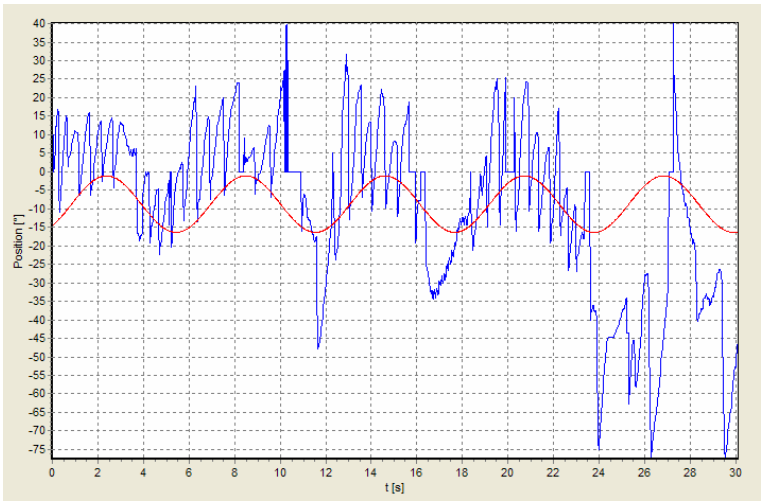

Figure 8: SPEM record measured on subject 3 before SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

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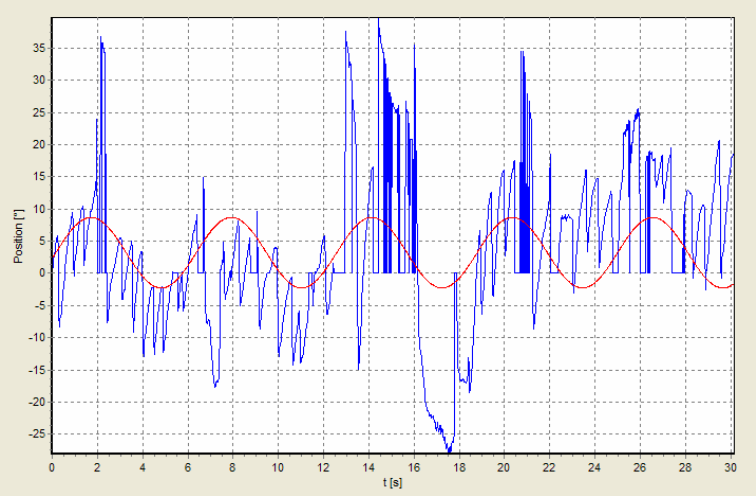

Figure 9: SPEM record measured on subject 3 after SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

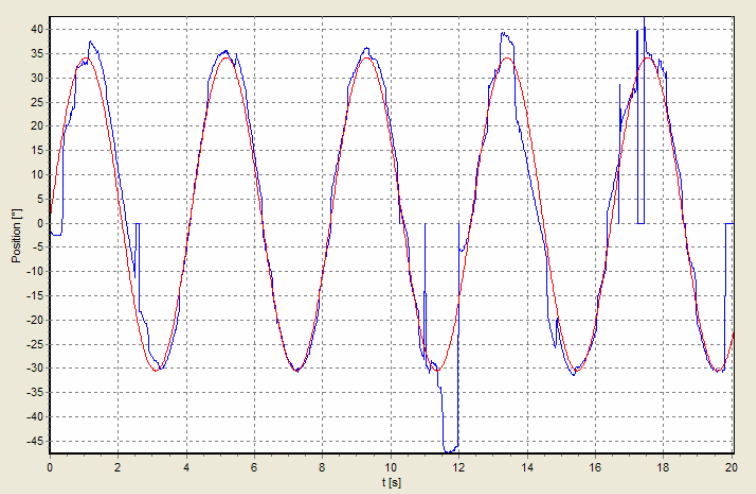

Figure 10: SPEM record measured on subject 4 before SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response
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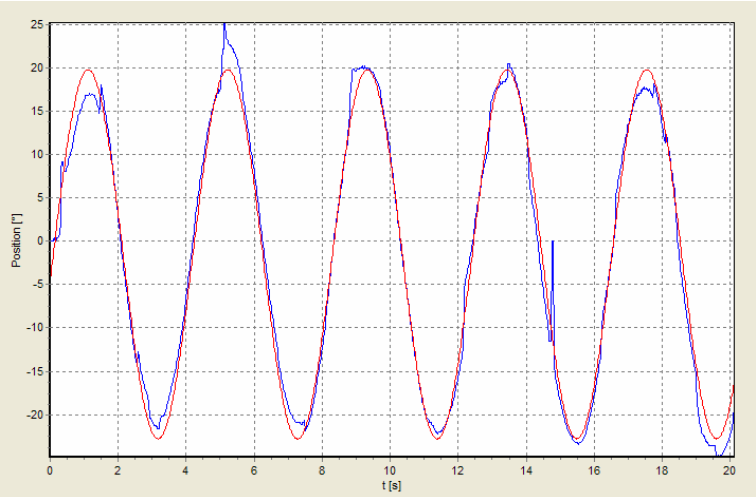

Figure 11: SPEM record measured on subject 4 after SPR. X-axis: time in seconds. Y-axis: horizontal eye position in degrees. Blue line: eye response signal. Red line: sine curve fitted on eye response.

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Conclusion

There can be a significant improvement of smooth pursuit eye movements quality observed in data of subject1 (both records), subject 2 and subject 4 after the selective posterior rhizotomy has been performed. The improvement is also clearly visible on the figures above. In case of subject 3, there is improvement in correlation coefficient and mean square error between the eye response and the target trace but the eye response remained bad. Subject 4 whose eye response were quite good, had also even better eye response after the SPR has been performed.

The selective posterior rhizotomy brought improvement in three of four cases we studied. No impairment has been observed.

The described method can bring useful values, when the oculographic record can't be evaluated by using traditional ways.

Acknowledgement

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References

[1] FASANO V.A., BROGGI G., BAROLAT-ROMANA G,, SGUAZZI A. (1978): ‚Surgical treatment of spasticity in cerebral palsy', *Childs Brain*. 4(5), p.289-305

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