Yu Qi, Fei-qiang Ma, Ting-ting Ge, Yue-ming Wang, Jun-ming Zhu, Jian-min Zhang, Xiao-xiang Zheng, Zhao-hui Wu, 2014. A bidirectional brain computer interface for effective epilepsy control. *Journal of Zhejiang University-SCIENCE C (Computers & Electronics)*, **15**(10):839-847. [doi:10.1631/jzus.C1400152]

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A bidirectional brain-computer interface for effective epilepsy control

Key words: Brain-computer interface, Epilepsy, Seizure detection, Responsive neurostimulation

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Summary

- **Objective**
  - Currently available treatments have shown limitations in seizure control. A promising choice for these patients is neurostimulation which delivers electrical current to neural tissue for treatment.
  - However, traditional continuous stimulations suffer from high side effects.
- **Method**
  - In this paper, a new BCI-based responsive stimulation system is proposed.
  - With an efficient morphology-based seizure detector, seizure events can be identified in the early stages, which trigger electronic stimulations only in response to seizure events. Therefore, the side effects could be reduced.
- **Results**
  - The proposed system was tested on rats with penicillin-induced epileptic seizures.
  - 83% of the seizures could be detected successfully with a short average time delay of 3.11 s, and the average seizure duration was reduced by 30.7%.

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Method: closed-loop system

Rat model of Penicillin

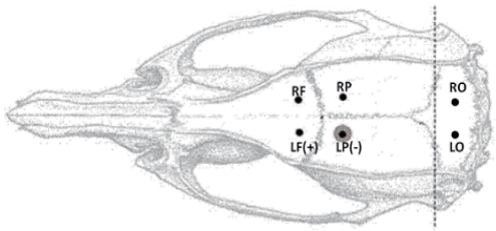
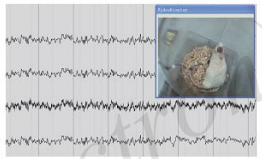


Fig. 1 Placement of cortical electrodes. Four screw electrodes of LF, RF, LP and RP are used for cortical signal recording and the stimulations are delivered from LF to LP. The LO and RO are used as ground and reference respectively.



Rat



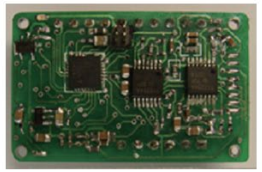
Signal acquisition system



Seizure detector

Seizure onset?

Yes

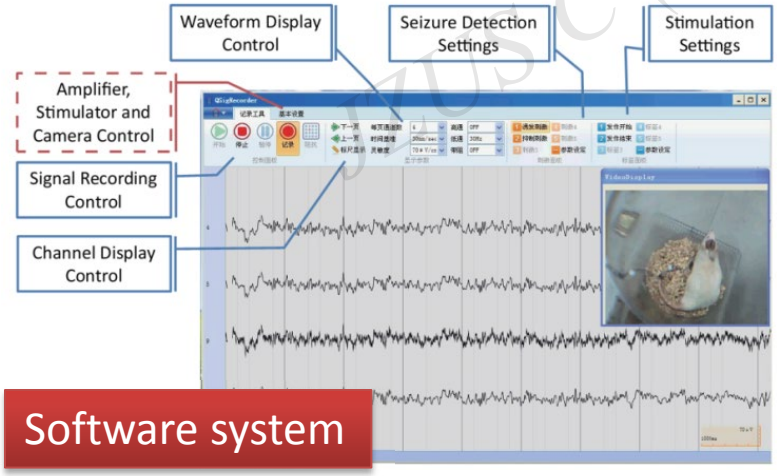


Current stimulator

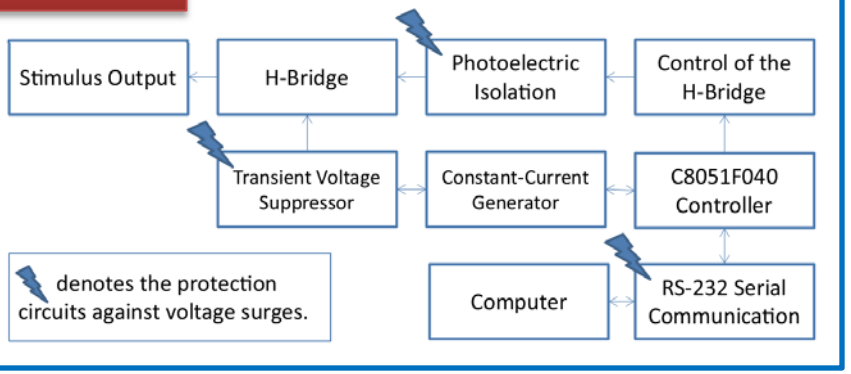
Deliver terminating stimulus

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Software system



Stimulator



Major results

Seizure detection

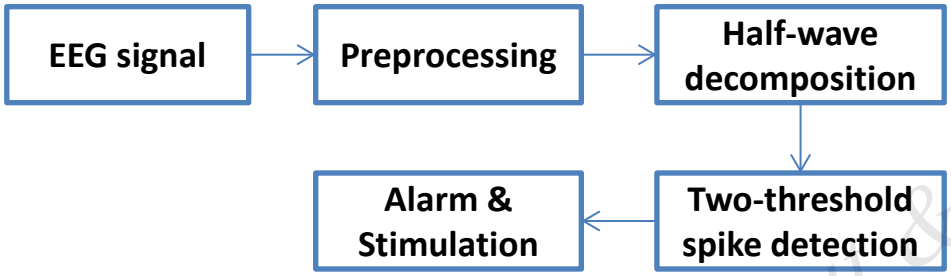


Table 3 Seizure detection results

Rat	Sensitivity	Specificity	TD (s)
1	0.84	0.79	3.43
2	0.95	0.60	2.70
3	0.81	0.72	3.68
4	0.81	0.64	3.27
5	0.86	0.56	2.26
6	0.91	0.89	2.66
7	0.85	0.55	2,42
8	0.57	0.91	4.45
Avg	**0.86**	**0.68**	**2.92**

83% of seizures are detected in 3 s.

Seizure suppression

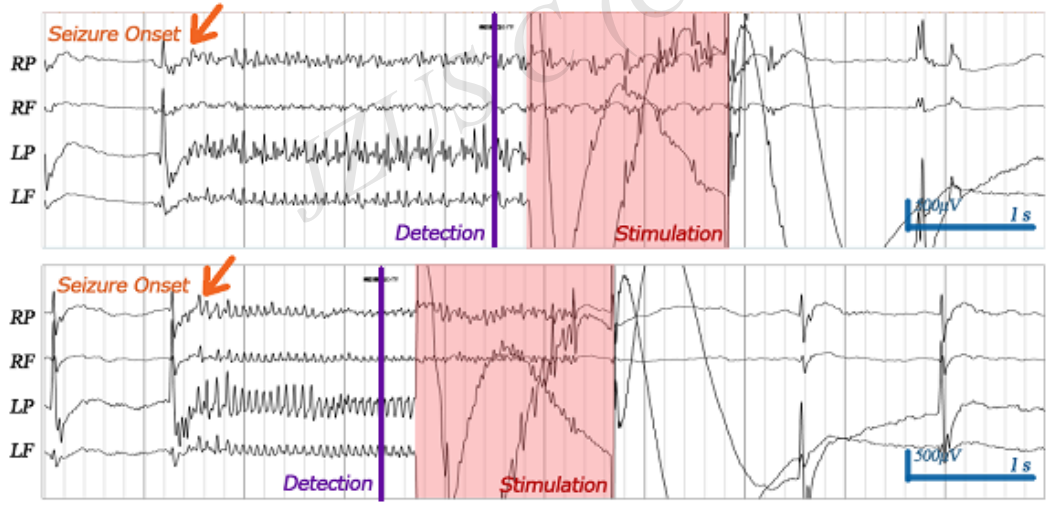


Table 5 Seizure suppression results

Rat	Stimulation Group		Control Group	
	Count	Duration(s)	Count	Duration(s)
1	277	8.71	147	13.24
2	207	9.70	288	21.52
3	168	10.22	106	14.60
4	289	7.89	268	18.43
5	271	9.43	277	10.60
6	363	14.06	103	13.99
7	309	9.16	144	11.86
8	602	11.80	205	12.65
Avg	**269.1**	**9.88**	**192.3**	**14.61**

Reduces seizure duration by 30.7%.

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Conclusions

- **Summary**
  - Online experiments showed that 83% of the seizures could be detected successfully with a short average time delay of 3.11 s.
  - With the therapy of the BCI-based seizure control system, most seizures were suppressed within 10 s.
  - Compared with the control group, the average seizure duration was reduced by 30.7%.
- **Conclusion**
  - Therefore, the proposed system can control epileptic seizures effectively and has potential in clinical applications.

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