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Coordinated control of an intelligent wheelchair based on a brain-computer interface and speech recognition

Key words: Brain-computer interface, Speech recognition, coordinated control, Intelligent wheelchair

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Motivation

- For paralyzed and aphasic patients, communication is often reduced to poor physical signals (e.g., electrooculograms, electromyograms, and electroencephalograms) or even a single sound (e.g., ‘ah’).

- An intelligent wheelchair is devised, controlled by a coordinated control mechanism based on a brain-computer interface (BCI) and speech recognition. By performing appropriate activities, users can navigate the wheelchair with four steering behaviors (start, stop, turn right, and turn left).

Our method

The proposed coordinated control mechanism includes a brain-computer interface and speech recognition, where the start is determined by P300 potentials, the direction by left-/right-hand motor imagery, and stop by speech (‘ah’). The coordinated control mechanism (Fig. 1) contains three algorithms:

1. P300 potentials for start;
2. Motor imagery for turning left/right;
3. Speech recognition for stop.

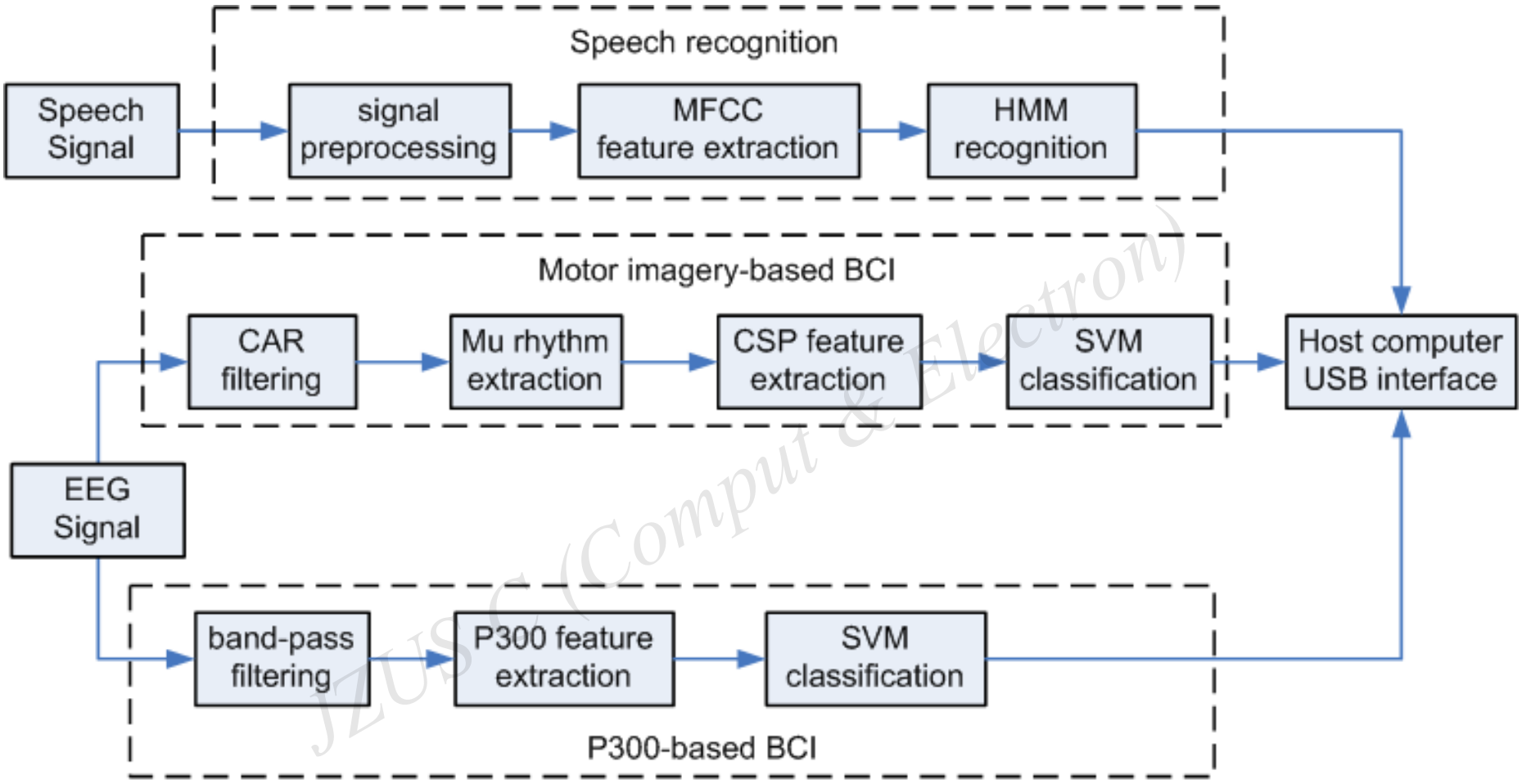

Fig. 1 Flowchart of the coordinated control mechanism, which consists of three parts: a speech recognition algorithm, a motor imagery based BCI algorithm, and a P300 based BCI algorithm

Experiments

The task of the indoor experiment was to navigate the wheelchair from the initial position and back to the initial position (destination) along a guide of ideal trajectories. Each trial contained the following steps: start the wheelchair with a constant speed of 0.3 m/s, turn right, turn right, stop and turn round, go back, and stop at the initial position (Fig. 2).

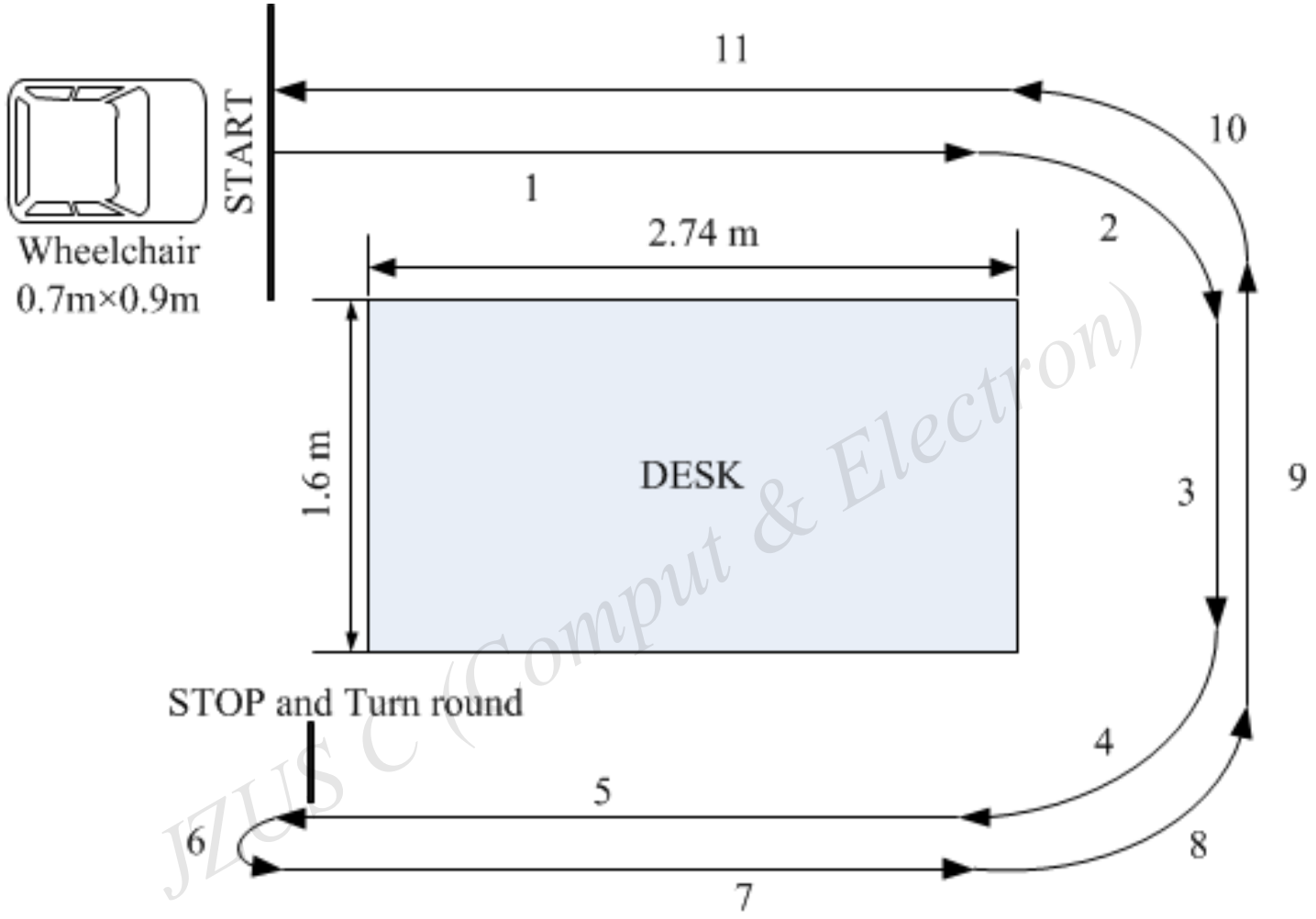

Fig. 2 The indoor environment experiment. The figure shows the initial position and ideal trajectories for the navigation task

Results

The results are summarized in Table 1. All the five users were able to complete the task successfully without collisions. The metric ‘path optimality ratio’ was satisfying and the time optimality ratio was remarkable due to fast and accurate decision making. The average response time was 1.2 s and the false positive rate was 0.0 per minute for stop by speech recognition in the indoor environment (the signal-to-noise ratio was 40–50 dB).

Table 1 Metrics for evaluating the intelligent wheelchair

Technical metric	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
Path length ±std (m)	21.7±0.5	21.4±0.3	21.5±0.4	22.1±0.5	23.0±0.3	21.7±0.5
Path opt. ratio	1.14	1.13	1.13	1.16	1.21	1.14
Time±std (s)	73±5	76±3	75±4	80±2	85±3	74±5
Time opt. ratio	1.11	1.16	1.14	1.21	1.29	1.12
Collisions	0	0	0	0	0	0
(Stop) RT± std (s)	1.3±0.3	1.1±0.3	1.4±0.4	1.2±0.5	1.0±0.2	1.2±0.4
(Stop) FAR ±std (/min)	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0