The results show that the *selected threshold- based onset detection method* was effective for CH 1, 2, and 3, which estimated the average number of times pushed around 7. However for CH4 and 6, the estimated average number of times pushed was around 2.

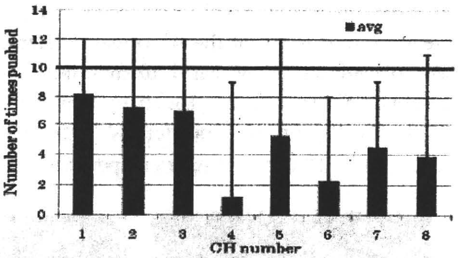

Fig. 4. Estimated number of times that valves were pushed by *selected threshold-based onset detection method for each CH*

To estimate the timings, CH1, which contained the best results for estimating the number of times that the valves were pushed, was selected. The estimation was conducted for subsets a, b, and c.

B. Use of Onset Detection Methods and Timing Information by Body Motion to Estimate Motion of Fingers

The features of the sEMG signals from one of the subjects were investigated by principal component analysis (PCA). The subsets of experiment I were limited to subsets a, b, and c in order to keep the analysis simple. The results analyzed using the timings provided externally are shown in Fig. 2(left), and the results of the same subject analyzed using the timings estimated by *selected threshold- based onset detection method* are shown in Fig. 2(right). The patterns of the valves are classified much better in Fig. 2(left) than in Fig. 2(right).

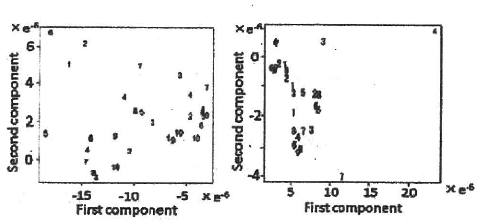

Fig. 5. PCA (left: timing is provided externally, right: onset detection method) *Numerical values show the order in which the valves were pushed in each valve pattern.
*Colors of the numerical values show valve patterns
(1st valve only: black; 2nd valve only: red; 3rd valve only: green)

C. Principal Component Analysis for Experiment II

Features of the sEMG signals from Experiment II were investigated by using principal component analysis (PCA). The PCA results (left: subject K, right: subject Y) for subsets a, b, c, and e are shown in Figure 6. As shown in Figure6 (left) shows that, the classification of the 1st and 2nd valve was not executed well for subject K, while Figure 6 (right) shows that, the 1st and 2nd valves were not well classified for subject Y.

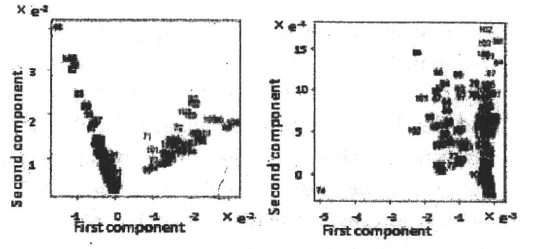

Fig. 6. PCA results for a, b, c, and e of Experiment II
(Left is subject A, and right: is subject B) *Numerical values show order in which the valves were pushed in each valve pattern.
*Colors of numerical values show valve patterns
(1st valve only: black; 2nd valve only; red, 3rd valve only: green)

D. Support Vector Machine

The same features used for the PCA were used for Support Vector Machine (SVM) analysis. Subsets a ~f from Experiment II were used as a training data set, and used to estimate the valve patterns for subsets d and e. Two kernel types, *linear*, and *Gaussian*, were used. The results of the estimation done by SVM are shown in Table I,II, and III.

TABLE I
ACCURACY OF SVM ESTIMATION FOR SUBJECT K

	Subject K					
Subset	g		h		i	
Kernel	radial	linear	radial	linear	radial	linear
A	80%	20%	50%	80%	73%	64%
B	100%	100%	100%	100%	100%	100%
C	80%	60%	73%	82%	0%	0%
D					60%	70%
E					100%	100%
F					17%	17%
Total	87%	60%	72%	86%	57%	57%

TABLE II
ACCURACY OF SVM ESTIMATION FOR SUBJECT Y

	Subject Y					
Subset	g		h		i	
Kernel	radial	linear	radial	linear	radial	linear
A	90%	90%	100%	60%	88%	50%
B	100%	100%	100%	100%	100%	100%
C	100%	100%	100%	100%	67%	83%
D					60%	20%
E					80%	60%
F					0%	40%
Total	97%	97%	100%	87%	73%	65%

TABLE III
ACCURACY OF SVM ESTIMATION FOR SUBECT K AND Y

	Subject K	Subject Y	Average
Linear kernel	66%	81%	73%
Radial kernel	70%	88%	79%
Average	68%	85%	76%

V. DISCUSSION

Selected threshold-based onset detection method [3] was used to estimate the valve pushed timings and Fig. 4 shows the estimated number of times that valves were pushed. Since each subset in experiment I had 10 trials, the ideal estimation results should be 10. However, number of times pushed varied depending upon electrode channels. These results show that precision of the method relies on selection of the right threshold, which requires further mathematical algorithm.

We selected CH1, which contained the best results for estimating the number of times that the valves were pushed, and used to obtain Fig.5 (right). Timing information provided externally was used to obtain Fig. 5 (left).

Each color on Fig. 5 represents the same valve pattern, therefore it is idealistic to be able to observe the same color in the same region. In Fig. 5 (left), all three patterns were located in distinct regions. On the other hand, in Fig. 5 (right), all three colors were assembled in disorder. These results suggest that externally providing timing information improves the precision of the estimation.

We conducted Experiment II to show the effectiveness of our proposed method, externally providing timing information using body motion. For both kernels, estimation for subject Y, a non-trained trumpet player, was 15% to 18% better than that of subject K, an experienced trumpet player. Our finding that the average estimation ratio of a non-trained trumpet player was better than that of a trained trumpet player when the hand postures were estimated using SVM, is attributed to the differences in their trumpet-playing ability. The non-trained trumpet player likely presented more overt characteristics for each of the valve patterns since his motions also included unnecessary movements. This strengthened the feature characteristics and enhanced the estimation precision of SVM.

VI. CONCLUSION

We showed that applying the timing information externally enables the motion of the finger to be estimated more accurately with the system developed. Also, we classified the valve patterns using two different types of kernels, and accurately distinguished all 6 valve patterns for playing the trumpet.

For future work, we plan to use timings from mouthpiece vibration as external triggers to estimate the valve patterns, and play the trumpet using the robot hand shown in Fig. 7.

Fig. 7. Robot hand playing the trumpet

REFERENCES

[1] American Association of Electrodiagnostic Medicine. Glossary of terms in electrodiagnostic medicine. Muscle Nerve. 2001;Suppl 10:S1-50.

[2] M. Zecca et al.: "Control of Multifunctional Prosthetic Hands by Processing the Electro myographic Signal," Critical Reviews in Biomedical Engineering, pp.459—485 , 2002

[3] G. Staude et al.: "Onset Detection in surface electro myographic signals," Proc. Journal on Applied Signal Processing, Volume2, pp.67—81, 2001

32nd Annual International Conference of the IEEE EMBS
Buenos Aires, Argentina, August 31 - September 4, 2010

Effect of simultaneous vibrations to two tendons on velocity of the induced illusory movement

Hiroaki Yaguchi, Osamu Fukayama, *Member, IEEE*, Takafumi Suzuki, *Member, IEEE*, Kunihiko Mabuchi, *Member, IEEE*

***Abstract*— A typical prosthetic limb has sensory shortcomings, one of which is lack of kinesthesia. Conventional methods to evoke kinesthesia, which would be required for a precise control of prosthetic limbs, include tendon vibration and skin stretch, but these produce only the sensation of small movements. In this study, tendon vibration is extended to evoke sensations of a more rapid movement. A stimulation method in which vibration is applied to two tendons is proposed, in contrast to most studies in which a single tendon was vibrated. Experimental results indicated that vibration applied to both ends of a muscle produces sensations of more rapid movement than vibration to just one. However, no significant difference in sensation was found between vibrating tendons of synergistic muscles and a single tendon.**

I. Introduction

Recent research has improved the functions of prosthetic limbs. However, most of these limbs do not provide a kinesthetic feedback. Strong efforts have been made to provide humans with kinesthetic and other somatosensory information [1], [2], but such information cannot approach the abundance and accuracy of human sensory systems. Kinesthesia provides feedback signals to the human motor system, and therefore, prosthetic limbs would require appropriate kinesthetic feedback for a precise control.

Group Ia muscle spindle afferents and some types of cutaneous mechanoreceptors are the main sources of kinesthetic information. Transcutaneous vibration to a tendon [3]-[6] (Fig. 1), which activates Ia afferents, and skin stretch near the joint[7], [8], which activates the cutaneous mechanoreceptors, together can induce a kinesthetic illusion in a non-invasive manner. However, these stimulation methods produce only sensations of small joint movements (e.g. [5], [6], [9]). That is, the resultant angular velocity was about 5-10 deg/s, while human joints generally required to rotate in tens deg/s. In this study, tendon vibration has been extended to evoke a sensation of a more rapid movement. We have narrowed our focus to elbow extension.

Macefield et al. [10] reported that microstimulation to a single Ia afferent fiber generally failed to evoke kinesthesia.

Manuscript received April 23, 2010. This work was supported in partly by Health and Labour Sciences Research Grant (H20-Nano-general-003) from the Ministry of Health, Labour and Welfare of Japan. Grant-in-Aid for Scientific Research (A) (20246045) from the Ministry of Education, Culture, Sports, Science and Technology

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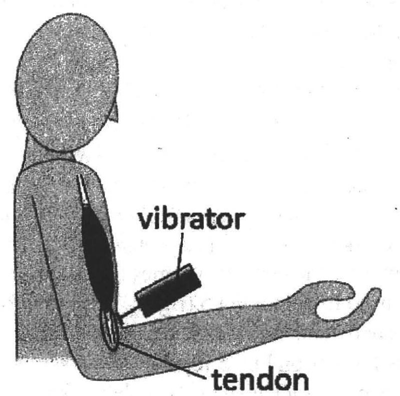

Fig. 1. Tendon vibration. A tendon is transcutaneously vibrated.

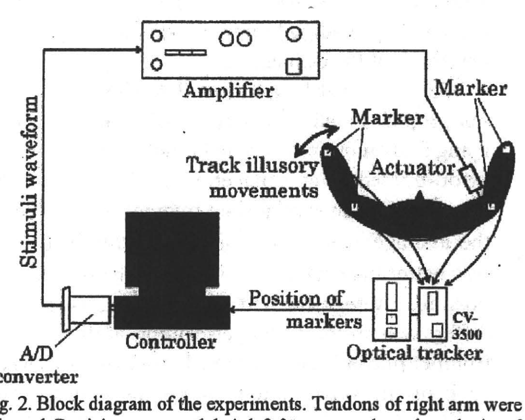

Fig. 2. Block diagram of the experiments. Tendons of right arm were vibrated. Participants moved their left forearm to show the velocity of the movement they felt in their right forearm. The arm positions were tracked optically to obtain angular velocity of forearms during vibration

This may imply that the central nervous system interprets the velocity to be zero based on the signals from the other Ia afferents. If this is true, a stimulation that activates numerous Ia afferents should evoke a sensation of rapid movement. In most studies, vibration was applied to a single tendon to evoke a sensation of a joint movement on one axis; however, generally several synergistic muscles are recruited for flexion or extension of a joint. Therefore, simultaneous vibration to synergistic muscles may evoke the sensation of a more rapid movement by activating Ia afferents of those muscles. Moreover, when a single tendon is vibrated, only some part of Ia afferents of the vibrated muscle generates an action

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potential per cycle[11]. Vibration to both ends of a muscle may produce greater activity because of more Ia afferents being stimulated, thereby resulting in a sensation of more rapid movement.

II. Methods

A. Experimental setup

Ten healthy volunteers participated in the experiment. Each participant was seated on a chair with his hands and forearms positioned horizontally on support tables.

Figure 2 shows a block diagram of the experiment system. Mechanical vibration was applied to the skin over the tendons. The vibration devices (Dia Medical System; DPS-270, Brüel & Kjaer; Type 1810) were driven by rectangular pulses. The peak-to-peak amplitude of the vibration was about 1 mm, the frequency was 100 Hz, and the duration was 10 s. Participants were instructed to close their eyes and wear headphones to prevent visual and auditory inputs. They were then instructed to indicate the movement velocity that they felt in their right arm by moving their left arm. To obtain the angular velocity of forearms during vibration, LED markers were attached to elbows and wrists of the participants, and these positions were tracked optically. The intensity of evoked kinesthesia was calculated by subtracting the angular velocity of the right arm from that of the left arm.

B. Vibration to both ends of a muscle

Vibration was applied to both ends of biceps brachii (BB) of 8 participants. While distal vibration was applied to the tendon, proximal vibration was applied to the muscle near the musclotendinous junction because the proximal tendons were located behind the other muscles. Vibration was applied to distal tendon and/or the proximal end 10 times each in a random order in 30 trials per participant. A rest interval of 3-4 min was provided after every 10 trials. After each rest interval and at the start of the experiment, it was confirmed that vibrations to either tendon evoked kinesthesia. A similar procedure was performed in the next experiment.

C. Vibration to synergistic muscles

Vibration was applied to the tendons of BB and brachioradialis muscle (BRM), both of which are synergists for elbow flexion. The distal tendons of BB and/or BRM were vibrated 10 times each in a random order in 30 trials per participant.

III. Results

A. Vibration to both ends of a muscle

Vibration to the distal tendon and/or proximal end of the BB evoked the sensation of a movement in all participants. The velocity of the illusory movement was 1.0 ± 0.7, 0.5 ± 0.4, and 1.7 ± 1.4 deg/s for the distal tendon, the proximal end, and both of the BB, respectively (Fig. 3). We conducted a Friedman test followed by a post-hoc Nemenyi test with vibration conditions ($\alpha = 0.05$). Significant differences were found between the vibration to the distal tendon or proximal end and to both.

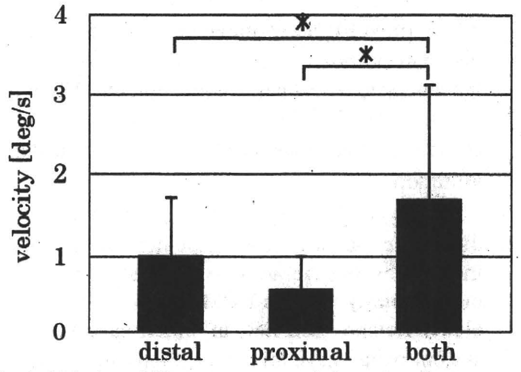

Fig. 3. Velocity of illusory movement induced by vibrating the distal tendon and/or proximal end of BB. The values are averaged over all participants. (*: $p < 0.05$)

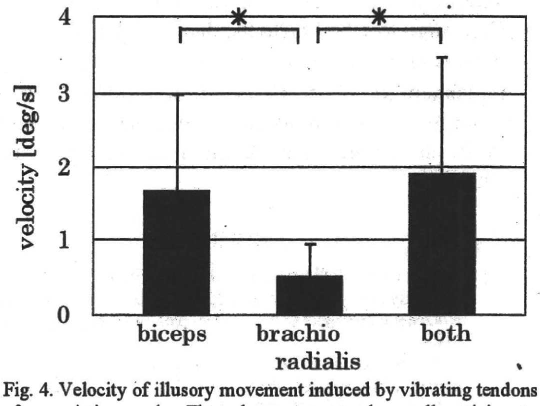

Fig. 4. Velocity of illusory movement induced by vibrating tendons of synergistic muscles. The values are averaged over all participants. (*: $p < 0.05$)

B. Vibration to synergistic muscles

Vibration to the distal tendons of BB and/or BRM evoked the sensation of a movement in all participants. The velocity of the illusory movement was 1.7 ± 1.3, 0.5 ± 0.4, and 1.9 ± 1.6 deg/s for BB, BRM, and BB + BRM, respectively (Fig. 4). As in the previous experiment, we conducted a Friedman test followed by a post-hoc Nemenyi test with vibration conditions ($\alpha = 0.05$). Significant differences in results were found between vibrations of BB and BRM, and between BRM and both.

IV. Discussion

Compared to vibration to the distal tendon or proximal end of biceps, vibration to both evoked a sensation of more rapid movement ($\alpha = 0.05$), although the velocity didn't reach that of large voluntary movements. This result seems to stem from increased activity of Ia afferents in the vibrated muscle. Tendon vibration activates not only Ia afferents but also cutaneous mechanoreceptors around the actuator. However, cutaneous receptors over the proximal end of the BB would not contribute to the kinesthesia of elbow movements, because the skin over that end of the BB doesn't be transformed by elbow movements. Moreover, the activity of pacinian corpuscles, which are vibration receptors, impairs the ability to detect passive movements [12] at joints near the actuator. Illusory movement would not be induced by the activity of cutaneous mechanoreceptors incidental to tendon vibration.

However, the results did not indicate any significant difference between the velocities of illusory movements induced by the vibration to BB and to BB and BRM. This may be partly because BRM makes a smaller contribution to elbow flexion than BB, in which case the central nervous system would have less of a response to its signals.

V. Conclusion

We extended tendon vibration, with a focus on elbow extension, to evoke a sensation of more rapid movement. Compared to vibration to the distal tendon or proximal end of the biceps, vibration to both evoked a sensation of more rapid movement ($\alpha = 0.05$). However, the velocity didn't reach that of large voluntary movements. Stimulation methods that can evoke sensations of more rapid movement require further study.

References

[1] K. Warwick, M. Gasson, B. Hutt, I. Goodhew, P. Kyberd, B. Andrews, P. Teddy and A. Shad, "The application of implant technology for cybernetic systems," *Arch. Neurol.,vol.* 60, no. 10, pp. 1369-1373, 2003.

[2] G. S. Dhillon and K. W. Horch, "Direct neural sensory feedback and control of a prosthetic arm," *IEEE Trans. Neural Sys. Rehabil. Eng.*, vol. 13, no. 4, pp. 468-472, 2005.

[3] D. Burke, K. E. Hagbarth, L. Löfstedt and B. G. Wallin, "The responses of human muscle spindle endings to vibration of non-contracting muscles," *J. Physiol.*, vol. 261, pp. 673-693, 1976.

[4] D. Burke, K. E. Hagbarth, L. Löfstedt and B. G.Wallin, "The responses of human muscle spindle endings to vibration during isometric contraction," *J. Physiol.*, vol. 261, pp. 695-711, 1976.

[5] G. M. Goodwin, D. I. McCloskey and P. B. C. Matthews, "The contribution of muscle afferents to kinaesthesia shown by vibration induced illusions of movement and by the effects of paralysing joint afferents," *Brain*, vol. 95, pp. 705-748, 1972.

[6] J. P. Roll and J. P. Vedel, "Kinaesthetic role of muscle afferents in man, studied by tendon vibration and microneurogram," *Exp. Brain Res.*, vol. 47, pp. 177-190, 1982.

[7] D. F. Collins and A. Prochazka, "Movement illusion evoked by ensemble cutaneous input from the dorsum of the human hand," *J. Physiol.*, vol. 496, no. 3, pp. 857-871, 1996.

[8] D. F. Collins, K. M. Refshauge, G. Todd and S. C. Gandevia, "Cutaneous receptors contribute to kinesthesia at the index finger, elbow, and knee," *J. Neurophysiol.*, vol. 94, no. 3, pp. 1699-1706, 2005.

[9] E. Rabin and A. M. Gordon, "Prior experience and current goals affect muscle-spindle and tactile integration," *Exp. Brain Res.*, vol. 169, pp. 407-416, 2006

[10] G. Macefield, S. C. Gandevia and D. Burke, "Perceptual responses to microstimulation of single afferents innervating joints, muscles and skin of the human hand," *J. Physiol.*, vol. 429, pp. 113-129, 1990.

[11] J. B. Fallon and V. G. Macefield, "Vibration sensitivity of human muscle spindles and golgi tendon organs," *Muscle Nerve*, vol. 36, pp. 21-29, 2007.

[12] N.S. Weerakkody, J.L. Taylor and S.C. Gandevia, "The effect of high-frequency cutaneous vibration on different inputs subserving detection of joint movement," *Exp. Brain Res.*, vol. 197, pp. 347-355, 2009.

ト面は薔薇や無臭が噴射された時よりも硬く知覚された。また、滑らかな標準面と同時に薔薇が噴射されると、テスト面は無臭が噴射された時よりも滑らかに知覚された。これらの結果は、香りと感触の相互作用の存在を示すものであり、香りの種類によって影響を及ぼす感触が異なることが示唆された。

40. 到達把持運動が手指の身体近傍空間に及ぼす影響

渋谷賢（杏林大学・医・統合生理学）

本研究は、到達把持運動が手指の身体近傍空間に与える影響を調べた。被験者は物体への到達把持運動と伴に、運動開始前、開始直後、開始 0.2 秒後のいずれかに示指もしくは母指に加わる触覚刺激の選択反応課題を行った。触覚刺激と同時に物体上の LED が点灯したが、被験者はこの視覚刺激を無視した。運動開始前の反応時間は示指と母指の間に差を示さなかったが、開始直後と開始 0.2 秒後の反応時間は視覚刺激の同時呈示により示指の方が母指よりも有意に早くなった。この相違は視覚刺激が呈示される空間に依存し、把持物体の手前よりも奥の空間の方が大きかった。また，この相互作用は視線の移動に影響を受けなかった.

41. 視覚方位刺激の検出に及ぼす触覚フランカー刺激の文脈的修飾効果

和田裕一（東北大学情報科学研究科），三坂慎一郎（東北大学情報科学研究科）

ある方位を持った線分刺激やガボール刺激の検出に際して，同じ方位を持つフランカー刺激が同一線上の隣接する領域に存在している場合，当該刺激の検出が促進（場合によっては抑制）される（たとえば Polat & Sagi, 1993)。ここで，物体の輪郭情報は触覚によっても検知できる点を考慮すると，フランカー刺激が触覚に提示される場合でも，上述のような刺激布置条件を満たしていれば，視覚に提示される方位刺激の検出が促進される可能性が考えられる。そこで本研究では，視覚刺激の検出に及ぼす触覚フランカー刺激のクロスモーダルな文脈的修飾効果について検討した。

42. 腱振動刺激によって錯覚される運動の速度に関する研究

矢口博彬 (東京大学)、深山理 (東京大学)、鈴木隆文 (東京大学)、満渕邦彦 (東京大学)

腱振動刺激は、筋紡錘一次終末の活動を誘発し、関節運動の錯覚を引き起こす。しかし、錯覚される運動の速度は、高々数 deg/s と低速である。本研究では、高速な運動の錯覚が生じない原因として、腱振動刺激によって興奮するのは、その運動に関わる筋に分布する一次終末の一部に過ぎないことに着目した。興奮する一次終末の数を増加させるため 2 点の同時振動を行い、錯覚される運動の速度における影響を調べた。その結果、ひとつの筋の両端で同時に振動すると、その一方のみ振動する場合と比べ、高速な運動の錯覚を生じた。本発表では、以上の結果に加え、運動感覚生成の義手への応用に向けた取組みについて、併せて議論したい。

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Presentation Abstract

Program#/Poster#:	782.12/PP8
Title:	Neural representation of motion signal after direction remapping in touch: Evidence from motion aftereffect
Location:	Halls B-H
Presentation Time:	Wednesday, Nov 17, 2010, 11:00 AM -12:00 PM
Authors:	***S. KUROKI**[1,2], J. WATANABE[2], K. MABUCHI[1], S. TACHI[3], S. NISHIDA[2]; [1]The Univ. of Tokyo, Tokyo, Japan; [2]NTT Communication Sci. Labs., Kanagawa, Japan; [3]Keio Univ., Kanagawa, Japan
Abstract:	The brain must realign information of tactile position and direction from the primary somatosensory maps to external coordinates in order to perceive the world appropriately. Although recent studies revealed sites of neural representations underlying remapping of positional information, a demonstration of neural representation for direction remapping was lacking. Here we psychophysically investigate whether the neural representation for direction remapping exists in the human tactile system using motion adaptation paradigm. We employed finger crossed posture to manipulate the relative spatial and somatotopic relations between fingers and compared the aftereffects of the inter-finger motions between normal and finger crossed posture. In normal posture, after adapting to a lateral motion between index and middle fingers, perceived motion direction was biased to the opposite direction to the adapted direction. In finger crossed posture, after adapting to the motion with the finger crossed, the posture was changed to normal one and test stimulus was presented. If the neural representation for direction remapping does not exist, the motion aftereffects could be observed in the somatotopic map, regardless of the postures. However, our results showed that the motion aftereffect was dominantly observed in the external coordinate, namely the perceived direction after adaptation is the same as the adapted direction in the somatotopic map. These findings firstly demonstrate the existence of neural representation for remapped motion direction, and in addition, imply that tactile

motion processing is dominantly performed using the remapped representation rather than somatotopic one. In order to investigate the relationship between the remapped representation and tactile conscious experience in motion processing, we conducted another experiment, in which participants placed their left index finger next to the finger crossed right hand. The motion stimulus was presented from right middle finger to the right and left index fingers simultaneously, and vice versa to give a confusing motion direction. Although the same motion stimuli used in the previous experiment were presented to the right hand, the motion aftereffect was not observed in this condition, demonstrating the dominance of remapped representation again, and close relationship between the remapped representation and tactile conscious experience.

Disclosures: **S. Kuroki:** Research Grant; JSPS research fellowship (20-10531), JST-CREST. **J. Watanabe:** JSPS research fellowship. **K. Mabuchi:** None. **S. Tachi:** JST-CREST. **S. Nishida:** None.

Keyword(s): TACTILE

MOTION PERCEPTION

ADAPTATION

Support: JSPS research fellow 20-10531

JST-CREST

[Authors]. [Abstract Title]. Program No. XXX.XX. 2010 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience, 2010. Online.

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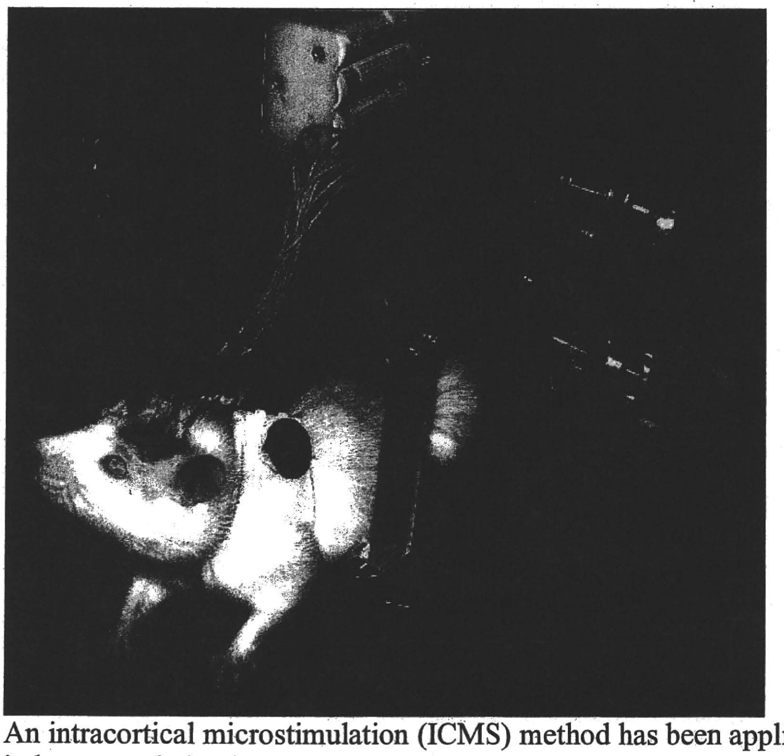
NEUROSCIENCE 2010

Presentation Abstract

Program#/Poster#:	294.9/HHH36
Title:	Correlation induction between cortical extracellular spikes pattern and locomotion states by microstimulation for a BMI control
Location:	Halls B-H
Presentation Time:	Sunday, Nov 14, 2010, 1:00 PM - 2:00 PM
Authors:	***O. FUKAYAMA**[1], T. SUZUKI[2], K. MABUCHI[2]; [1]Univ. of Tokyo, Tokyo, Japan; [2]The Univ. of Tokyo, Tokyo, Japan
Abstract:	



An intracortical microstimulation (ICMS) method has been applied to induce correlation between neural extracellular potentials and locomotion states for a brain-machine interface (BMI) control. Our BMI system is in the form of a small vehicle (attached figure), which we call the RatCar, integrating an animal body with the BMI device. A state space representation model correlated extracellular spikes patterns in motor cortices with locomotion velocity and directional changes. First, the vehicle was towed by a rat recording neural activities and locomotion states simultaneously to determine the correlation. Then, the vehicle was controlled according to the estimation by the model. However, spikes pattern did not always show a strong correlation with locomotion which resulted in less-accurate estimation. Methods to search for "good" neurons (i.e., strongly correlated to locomotion) or to forcibly correlate a neuron with objective tasks has been needed. Here, we focused on functional plastic changes induced by ICMS. A preliminary study to correlate neural spike patterns to lever pressing task was achieved using male Wistar rats. First, they were trained to press a lever in a cage to earn food rewards. They had neural electrodes implanted in its motor cortices to observe neural firing rates followed by the lever pressing action. Then, an ICMS was applied to their motor cortical regions synchronized to the lever press. Finally, the neural firing rates were compared to those in the previous sessions. As a result, the firing rates significantly increased in several subjects. It suggests that the method is promising to improve the locomotion estimation performance by modifying a feature of neurons incidentally nearby recording electrodes.

Disclosures: **O. Fukayama**, None; **T. Suzuki**, None; **K. Mabuchi**, None.

Keyword(s): CORTICAL PLASTICITY

MOTOR CONTROL

RAT

Support: Research grants (No. H20-nano-general-003) from the Ministry of Health, Labour and Welfare of Japan

[Authors]. [Abstract Title]. Program No. XXX.XX. 2010 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience, 2010. Online.

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NEUROSCIENCE 2010

Presentation Abstract

Program#/Poster#: 85.9/AAA17

Title: Improvement of a flexible Parylene ECoG electrode for long-term stable recording

Location: Halls B-H

Presentation Time: Saturday, Nov 13, 2010, 1:00 PM - 2:00 PM

Authors: ***T. SUZUKI**[1], N. KOTAKE[2], O. FUKAYAMA[1], S. TAKEUCHI[3], H. WATANABE[4], T. ISA[4], H. SAWAHATA[5], H. TODA[5], I. HASEGAWA[5], K. MABUCHI[1];
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Abstract: The electrocorticogram (ECoG) has recently attracted attention as a source signal for brain-machine interface (BMI) systems because of its good balance of features: it is less invasive than penetrating electrode methods and has a higher spatial resolution than the normal EEG. In order to obtain basic data for the development of BMI and to bring it to clinical application, it is essential to achieve long-term stable recording with this technique. We have been developing various kinds of neural probes based on a flexible Parylene-C substrate. These probes are easy to form into various kinds of structure and have good compatibility, which enables them to be integrated with various functions. Using these properties, we have developed penetrating type probes, probes with microfluidic channels, and ECoG electrodes with a mesh structure for an improved fit to the surface of the brain. However, there is no report on the compatibility of platinum black with Parylene probes. In this study we examined the problem in terms of mechanical properties under various plating conditions and the stability of recording. We used several types of flexible neural probes based on a Parylene-C polymer substrate. The typical probe has a mesh structure with an array of 25 (5 × 5) σθυαρε (800 × 800 μμ) ηολεσ. Τηερε αρε 32 ρεχορδινγ σιτεσ λοχατεδ ωηερε τηε βεαμσ χροσσ (200 μμ ωιδτη). Τηε ιντερελεχτροδε

διστανχε ισ 1 μμ. Εαχη ρεχορδινγ σιτε ισ σθυαρε ιν σηαπε (50 × 50 μμ). Τηε σιζε οφ τηε χομπλετε μεση ισ 6 × 6 μμ, ανδ α χαβλε λεαδσ το α παδ ωιτη α χοννεχτορ. A layer of gold (thickness, approximately 200 nm) was sandwiched between two 10-µm-thick layers of Parylene-C. This gold layer acts as both a conductor and a recording site. The exposed surface of the gold (recording site) is plated with platinum black under various conditions. We evaluated the problem in terms of electrical impedance, mechanical properties, and the stability of recording of neural signals.

Disclosures: **T. Suzuki**, None; **N. Kotake**, None; **O. Fukayama**, None; **S. Takeuchi**, None; **H. Watanabe**, None; **T. Isa**, None; **H. Sawahata**, None; **H. Toda**, None; **I. Hasegawa**, None; **K. Mabuchi**, None.

Keyword(s): MULTIELECTRODE

MICROELECTRODE

ECoG

Support: Strategic Research Program for Brain Sciences

[Authors]. [Abstract Title]. Program No. XXX.XX. 2010 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience, 2010. Online.

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演題３：末梢神経障害による感覚障害に対するマイクロスティミュレーション法を用いた感覚補填・感覚強化システムモデルの構築

A model of the sensory prosthetic and enhancement system for sensory disturbances due to peripheral neural disorders using micro-stimulation method

抄録：末梢神経傷害による感覚機能障害に対して、マイクロスティミュレーション法を用いて感覚機能の補填・強化を行なうシステムのモデルの構築を行なった。まず、正中神経にマイクロニューログラム針電極を刺入して SA-I single unit に当てる。次に、その投射野の指に、外部からの圧刺激が直接指の圧受容器に影響しない様に硬いプラスチックの指サックを被せる。さらにその上に圧センサを装着してこれをバーで押し、検出された圧を電気刺激パルス列に変換し、マイクロスティミュレーション法を用いて unit の電気刺激を行ない、圧感覚を発生させた。その結果、検出した圧を電気刺激パルス列の繰り返し頻度に変換する係数を調節する事により、加えた圧と同じ強度の圧感覚を発生させる事が出来、又、弱い圧を強い圧として強化・提示する事も可能である事を示した。なお、電気刺激により発生する圧の強さの評価は、被験者が反対の手で圧センサを押し込み提示するという方法を用いた。

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演題２：SA-I mechano-receptive units の圧ー発火特性に関する検討

ー preliminary study ー

Classification of the SA-I mechano-receptor by the relationship between the applied pressure and the repetitive frequency of the generated spikes - a preliminary study -

抄録：我々は感覚機能を持つ義手の開発に関連して SA-I mechano-receptive unit に電気刺激のパルス列を加えて、人為的に任意の強度の圧感覚を発生させる研究を行なっている。その実験手順として、電気刺激を行なう前に、まず、マイクロニューログラム法によって、SA-I 機械受容器に与えた圧と unit に発生する発火頻度の関係を検討しているが、同じ SA-I unit でも圧ー発火頻度特性は同じではなく、異なるサブグループが存在するという結果を得ており、現在、圧ー発火頻度特性によって分類した場合、いくつのクラスタに分かれるか、についての検討を行なっている。まだ preliminary な段階ではあるが、これまで得られた結果について報告を行ない、このように複数の特性を示す受容器が存在する意義について考察を行なう。

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BLOGS // AUTOMATON

Researchers Using Rat-Robot Hybrid to Design Better Brain Machine Interfaces

POSTED BY: TIM HORNYAK / 月, 10月 04, 2010

A strange creature, half robot, half rat, has been seen scuttling across a laboratory in Japan. It's RatCar, a rat-vehicle experiment that scientists hope could lead to improved mobility for people with disabilities.

Researchers at the University of Tokyo wanted to see whether rats could control a miniature vehicle through the brain signals that move their limbs. They recently presented their project at the IEEE Engineering in Medicine and Biology Society annual conference in Buenos Aires, Argentina.

"We wanted to develop a brain-machine interface system aiming for future wheelchairs that paralyzed patients can control only with thought," says Osamu Fukayama of the university's Medical Engineering and Life Science Laboratory. "RatCar is a simplified prototype to develop better electrodes, devices, and algorithms for those systems."

Unlike some brain-machine interface, or BMI, devices that rely on noninvasive EEG to detect neural activity, the RatCa works through direct contact with the brain. Other researchers have used this technique in getting rats to control robotic grippers and monkeys to control computer cursors and even advanced robot arms.

In the RatCar, tiny neural electrodes [the dark dots on the tip of the device shown on the photo, right] were implanted ir the motor cortex of rat brains, and the animals were suspended under a lightweight, motorized "neuro-robotic platform" with wheels. The objective was to make the vehicle collaborate with the rats to achieve the locomotion they desire.

The rats were trained on the car by towing it around an enclosed area with the motors disengaged. A vision system positioned above tracked the rats by following colored markers on their backs and the vehicle. It fed the positions into a "locomotion estimation model" program that correlated the motion of the animals with readings from the electrodes.

Next the rats were suspended more tightly to the car so their limbs touched the floor only slightly. The researchers then switched the system into "neuro-robotic mode," with the neural signals used to help drive the car. Six out of eight rats used in the study adapted well to the car.

"The vehicle moved forward synchronously with a rat when it was placed inside," says Fukayama, but he adds that the degree to which the car was being controlled by the rat itself was unclear.

Since the rat would be forcibly moved along with the car, measuring its real intentions became a challenging problem. Another difficulty was that only a small percentage of the electrodes actually recorded neural activity, and the recorded neurons didn't necessarily correlate with target movements.

Fukayama and colleagues Takafumi Suzuki and Kunihiko Mabuchi plan to perform more experiments to address the uncertainties. They want to confirm that the rats can drive the car in different directions and also measure the force that the rats are exerting when trying to move under the car. That way, they could track differences in its motion and the rats' apparent intentions.The less force, the better the neural link is working.

Rats have helped bring about many medical breakthroughs, and we'll see whether they'll help make thought-controlled wheelchairs commonplace.

Images: University of Tokyo's Medical Engineering and Life Science Laboratory

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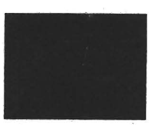

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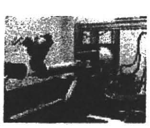

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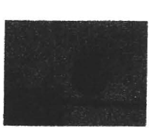

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第 15 回日本バーチャルリアリティ学会大会論文集 (2010 年 9 月)

触運動知覚の刺激周波数による違い

Difference of tactile motion perceptions depending on stimulation frequency

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Abstract : To explore whether tactile motion processing integrate or independently process the responses from different mechanoreceptors, we psychophysically studied human judgments of the apparent motion perception between two vibrations on index and middle fingers. Results from low and high frequency vibration conditions clearly showed different transition of states: Motion perception occurs with short onset time difference with low-freq vibration, while two points vibration tend to degenerate single point with high-freq vibration, which suggests independent motion mechanisms on responses from each mechanoreceptor.

Key Words: *tactile, Phantom Sensation, Apparent Motion, temporal order judgment*

1. はじめに

私たちの皮膚の内側には，様々な形の機械受容器が埋まっている。各受容器はそれぞれ異なる機械フィルタとして皮膚の変形を符号化し，神経信号を生成する。脳はこれら符号化された信号から外界を推定しているわけであるが，一体異なる符号化情報はどのように組み合わされ，あるいは別々のまま，処理されているのだろうか。

機械受容器による符号化の一つの要素として皮膚に加える振動の周波数があり，低周波に高い感度を持つ RA と高周波に高い感度を持つ PC の二つの系について，さまざまな処理に対する系の独立性が調べられてきた [1]。マスキングや順応といった単純な入力二信号の相互作用は異なる周波数帯に渡っては生じないことから，脳における初期の信号処理においては各々の系は混ざっておらず，独立に処理されていることが示唆されている。本稿では，もう少し複雑な入力信号の関係性として運動の知覚を例にとり，運動が入力の系ごとに検出されているのか，統合後に検出されているのかについて調べ進める。具体的には入力信号の振動周波数帯制限によって RA/PC 系の選択的刺を行い，異なる条件下での「刺激定位位置」「運動生起確率」「運動方向判断」を調べることによって，運動検出メカニズムの比較検討を行った。

2. 触運動知覚の実験

皮膚上の二点に振動が加わるとき，同時や逐次といった知覚に加え，ほぼ同時に加えられた二点の振動が一点に縮退して定位されるファントムセンセーション [3] や，振動に適切な時差を持たせると二点間になめらかな運動が知覚される仮現運動 [2] が生じることが知られている。本実験では，刺激開始時間間隔（SOA）を変数とする知覚状態の変化が，入力振動の周波数に依存するか否かを調べた。

2.1 実験装置

2 つの積層圧電アクチュエータ (NEC/TOKIN ASB680) の円柱を時間差をつけて振動させて皮膚を刺激した。一方の振動が他方に伝搬することを避けるため，振動は別の指に印加された。直径 12mm の円柱は，指を置く板に開けられた径 14mm の穴の下からのぞくように 25mm 間隔で配置されており，被験者は左手の人差し指及び中指の指腹部が円柱にあたるように指を置いた（図 1）。各円柱は低周波条件

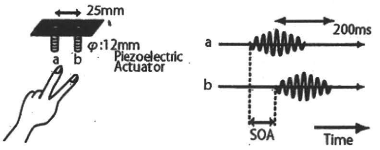

図 1: 実験における刺激点の位置，刺激タイミング

20Hz 高周波条件 250Hz で駆動し，振幅をサインカーブ状に変化させて 200ms 間振動させた。本実験においては，RA 系と PC 系の神経を可能な限り選択的に活動させる事が肝要であるため，刺激の最大強度は予備実験で計測された知覚閾値の 25 倍相当の強度（20Hz 条件では $70\mu m$, 250Hz 条件では $7\mu m$）を用いた。これらの値は，選択刺激を行っている先行研究 [1] で用いられてきた値を参考に定めてある。

2.2　実験手順

被験者は二本の指に時差を持って加えられた 20Hz ないし 250Hz の振動のペアについて「一点定位，二点定位，運動，二点順次」のうちから一つの状態を選んだ上で，どちら向きの運動 (順序) と知覚されたかを「右向き/左向き」の強制二択で回答する．テスト刺激の SOA は-140ms から 140ms 間の 20ms おきに 15 通り（負の SOA は左側のピンが先に提示されたことを意味する）とし，振動周波数 2 条件× SOA 15 条件× 20 試行，計 600 試行を 10 セッションに分けて行った。経時変化の影響を避けるため，各セッション中の SOA 提示順及び周波数はランダムとした。被験者は著者を含め，24 才から 27 才の計 5 名である。

2.3　実験結果

5 名の被験者の回答を平均した値を図 2 に示す。

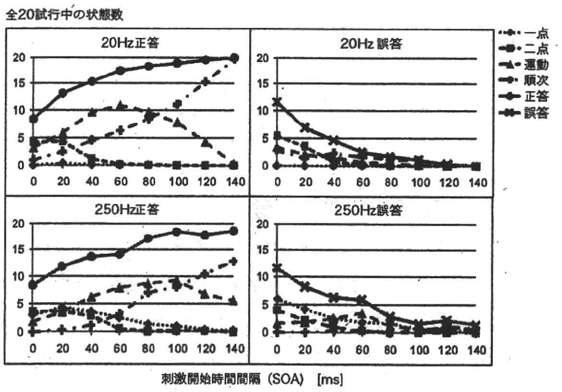

図 2: 知覚される状態と方向判断の正・誤答率の変化

横軸はテスト刺激の SOA[ms] の絶対値，縦軸は各状態を回答した回数の平均であり，正しい方向が知覚された場合を左列のグラフに，誤った方向が知覚された場合を右列のグラフに分割して描画してある。テスト刺激の SOA が増加し，提示される運動が明らかになるに従って正答確率が増加 (左列グラフ○印)，誤答率が低下（右列グラフ×印）しているが，低周波 (上段) に比べ高周波 (下段) の方がなだらかに変化しており，精度が低いことが見てとれる。正答時の状態変化に着目すると，低周波の方が運動感 (△印) を得るのに必要な SOA が短く，二点順次 (+印) と知覚する回数が多いことがわかる。一方の誤答時は，低周波で二点順次と知覚した誤答が比較的多いのに対し，高周波では運動を知覚した上での誤答が SOA を大きくしてもなかなか減らない傾向にある。また，正答・誤答両方の場合について，低周波では一点と知覚される事 (◇印) がほぼ無いのに対し，高周波では一点知覚が生じやすく，その時の正答率は高くない事がわかる。各状態の知覚される割合や，その変化する時間帯については個人差が大きかったが，上記の傾向は全ての被験者について見られた。

3.　考察

運動方向判断や順序判断の研究の多くは，それらが各受容器からの入力の統合後に判断されているという前提の元，様々な振動子を用いて実験されてきた [4, 5]。今回，入力周波数帯を限って実験することにより，高周波振動による提示では運動の属性の一つである “方向” の判別が困難なことが示された。高周波振動ではファントムセンセーション (二震源の中央一点定位) が生じやすいという結果は先行研究 [3] での報告に良く合うものであるが，SOA の増加に伴い一方の振動による他方のマスキング (二震源の左/右一点定位) が生じるというケースも観測された。その結果，方向判断に必要な空間位置の情報が失われてしまったと考えられる。また，運動に関してもその輪郭や方向があいまいであるといった主観報告もあり，高周波振動においては個別の信号の時間・空間情報が，低周波に比べ明瞭に区別できていない可能性がある。一方の低周波振動に関しては，振動の包絡線や円柱のエッジといった “形” の情報を振動子の位置にはっきりと感じたといった意見が聞かれた。これは提示振幅そのものが高周波の 10 倍である事に起因するとも考えられるが，そもそも触知覚システムが位置や形，テクスチャといった情報を別の経路で処理している可能性も考えられる。

4.　おわりに

本研究では，触運動知覚への入力周波数の影響を心理物理実験により考察し，方向判断精度及び状態遷移の違いを観測した．今後，各々の系について運動の検出メカニズムのモデルを立て，実験的に検証していく事が考えられる．

謝辞

本研究は特別研究員奨励費（20·10531）及び JST-CREST「人間調和型情報技術」研究領域の助成を受けたものである。

参考文献

[1] G.A. Gescheider, J.H. Wright, R.T. Verrillo: Information-Processing Channels in the Tactile Sensory System. Psychology Press, 2009.

[2] C.E. Sherrick,R. Rogers: Apparent haptic movement. Perception & Psychophysics, Vol.1, pp.175-180, 1966.

[3] G. von Bekesy: Similarities between hearing and skin sensations, Psychological review, Vol.66, pp.1-22, 1959.

[4] A. Gallace, et.al.: Response requirements modulate tactile spatial congruency effects, Experimental Brain Research Vol. 191, No. 2, pp. 171-186, 2008.

[5] S. Yamamoto, S. Kitazawa: Reversal of subjective temporal order due to arm crossing, Nature neuroscience, Vol.4, No.7, pp.759-765, 2001.

ラット末梢神経系の運動指令信号を用いた歩行状態模倣ロボットの開発

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Development of a prosthetic device to mimic locomotion of a rat controlled by mortor siganls in the peripheral nerves

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Abstract

In this study, peripheral nerve signals have been applied to control a prosthetic device for rat limbs. First, a pattern detection algorithm estimated limbs movement of a rat according to chronically recorded signals from the sciatic nerves. As a result, the device mimicked the estimated movement of the rat to drive itself.

キーワード：神経インタフェース 慢性電極 歩行動作推定 末梢神経 ラット 運動制御
(neural interface, chronic electrodes, locomotion estimation, peripheral nerves, rat, motr control)

1. はじめに

神経信号を用いて，デバイスの制御を行う神経インタフェースの研究はBMI(Brain-Machine Interface)という呼び方が定着してきていることからもわかる通り，多くの研究で中枢神経である脳から計測してきた信号を用いている．それに対して，電極埋め込み時のリスクの低さや，対応部位の明確さ等から末梢神経信号を用いる末梢神経インタフェースの研究も進められており，実現例としては，人の末梢神経信号を用いて離れた場所にあるロボットアームを動作させるといったものがある(1)ものの，末梢神経インタフェースの実現例は現状で乏しい．また，BMIの多くの研究では制御を行うロボットアームといったデバイスは使用者から離れた位置にある．それに対して，制御を行うデバイスが直接使用者に触れているシステムであれば，デバイスの動作による直接的な視覚や触覚フィードバックを与えるとことができると考えられる．これにより，電動車椅子といった実際の応用に近い形の使用の影響を観察することができる．この種のシステムとしては，深山らによってRatCarシステムというものが考案されている(2)．このシステムでは，ラットの中枢神経を用いて，歩行を代替する形でラットを搭載しているデバイスの動作を行っている．

これらを踏まえ，本研究では，ラットの末梢神経信号を利用した歩行模倣ロボットシステムの開発を行った．具体的には，ラットの坐骨神経表面に神経電極を貼り付ける形で埋め込み，計測された信号に基づいてラットの運動指令に沿った脚の駆動を目指すものである．本システムの特徴は，末梢神経信号から左右の足の動作推定に基づいてデバイスの制御を行うことにより，ラットの歩行を模倣したような動作ができることである．また，もう一つの特徴として，信号計測を行うラットと制御するデバイスが一体となって移動可能な構造を有することによる，直接的な視覚，触覚フィードバックを与えた際の末梢神経インタフェースの使用による影響を観察できることである．

著者らは，オンライン使用可能な末梢神経信号からの脚の動作推定，推定に応じたデバイスの制御を実現した．本稿では，本システムの紹介と性能評価，また本システム構成において見られる要素技術の改善点についての検討を行う．

2. 歩行模倣ロボット

図１に歩行模倣ロボットシステムの構成を示す．実験にはオスのWistar系ラットの成獣を用いた．本システムにおける研究内容は大きく３つに分けられる．１つ目はラットの坐骨神経からの神経信号計測，２つ目は計測信号から足の動作推定，３つ目は推定結果に追従する形でのデバイスの動作の制御である．以下ではその３つの要素に関して詳説する．

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