別紙様式第１３号（論文内容の要旨及び論文審査の結果の要旨）

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論 文 内 容 の 要 旨

Nowadays, a large number of machines are being produced to improve human life quality. Some conventional machines are usually controlled by hand such as keyboard and the others are controlled by foot like pedal of car. The next stage of communication method between machine and human are biometric technology. There are three of the famous biometrics: finger prints, voices, and iris. They have been bring a revolution for the communication between human and machine. Biometrics are widely used in identification system based on the physical and behavior characteristic.

Then bio-signals also took a role to improve the quality of communication between human and machine. One of the bio-signals that is widely used in neuroscience is electrooculography (EOG). This signal comes from eyes activities such as gaze motions and blinks. Eye activities change the magnitude of potential between cornea and retina. On one hand, biometrics are well-known used in switch based control such as on the security system, and on the other hand, EOG signal has switch and proportional functions. EOG signal compared to electromyography (EMG) and electroencephalography (EEG) also has a linear relationship with gaze motion distance, relatively high amplitude and been easy detected, EOG has a bright future to be investigated to develop the proportional bio-signal.

This research used NF Instrument as the EOG sensor. This device has an amplifier (head box), a processors box, and four electrodes. The electrodes consist of a ground electrode, minus (reference) electrode, channel 1 (Ch1) and channel 2 (Ch2). Three digital filters were given by the processor box which is 1.6 Hz High Pass Filter, 60 Hz Low Pass Filter and 60 Hz Ham Filter. Another 60 Hz Low Pass Filter was added to reduce the electricity equipment noise.

One of the factors influences the stability of EOG signal is the position of electrodes. Using the NF instrument, six possibilities of electrode positions were investigated under the right eye for Ch1 and other 6 candidates of electrode positions beside the left eye were also inspected for Ch2.　A camera was used to detect gaze motion distance. Ch1 acquired the signal from vertical gaze motion and Ch2 detected the signal from horizontal gaze motion. Stability of signals was decided from signal magnitude and standard deviation. The result shows that linear approaching to this condition successfully detect the gaze motion in horizontal or vertical case with average error pixel around 80 pixels or 1.6 cm. Based on this result, we concluded that a good quality of EOG signal is necessary to develop EOG applications in human-machine interface. Using the appropriate position of EOG electrodes, this signal was used to control robot manipulator in four directions (up, down, left and right). This was a real time system since it could detect when a signal comes and sent it to the robot manipulator system through Arduino microcontroller. Positive and negative threshold were used to detect gaze motions. Ratio between maximum and minimum value of EOG from Ch1 was used to distinguish the signals from up gaze motion and blink. The result shows that this system was successfully detect the gaze for up, down, right or left. Based on the accuracy of this system, we can use this method for some extend applications later.

A simply rotation matrixes were introduced to help operator move a 2-dof planar robot manipulator not only in horizontal or vertical but also in diagonal gaze motion. The robot movement was the indicator this system could follow gaze motion based on EOG. Operators looked into five training target points each in horizontal and vertical line as the preliminary experiments which based on directions, distances and areas of gaze motions. It was done to get the relationships between EOG and gaze motion distance for four directions: up, down, right and left. The maximum angle for horizontal was 46°while it was 38°in vertical. Rotation matrixes were attached to combine the horizontal and vertical signals, so it was possible to diagonally track objects. To verify, the errors between actual and desired target positions were calculated using Euclidian distance. This test section had 20 random target points. The result shows that this system could track an object with average angle errors are 3.310 in x-axis and 3.580 cm in y-axis.

To improve the ability of tracking object using EOG, affine transform method was proposed with robot manipulator movements as the indicator. Three operators looked at 24 target points displayed on a monitor that was 40 cm in front of them. Two channels (Ch1 and Ch2) produced EOG signals for every single eye movement. Combinations of signals between the two channels were used to make this system not only for horizontal or vertical gaze motion but also for diagonal motion in analog locations. These signals were converted to pixel units by using the linear relationship between EOG signals and gaze motion distances. The conversion outcomes were actual pixel locations. An affine transform method is proposed to determine the shift of actual pixels to target pixels. This method consisted of sequences of five geometry processes, which are translation-1, rotation, translation-2, shear and dilatation. The accuracy was approximately 0.86°±0.67° in the horizontal direction and 0.54°±0.34° in the vertical. This result shows that the method is reliable in building communication between humans and machines by EOGs.

Flexibility of tracking system using EOG was studied by controlling a 3-dof in 3-dimensional area. Five features of EOG: threshold; slope of signal; integral of absolute EOG signals; peak and half period of a wave, were used to detect EOG signal, convert EOG signal to gaze distance and distinguish gaze motion, voluntary blink and involuntary blink. The targets were displayed on a monitor from two camera, front and top views. The active camera could be chose by voluntary blinking. EOG signals were converted to pixel coordinate using affine transform. The pixel coordinate was transform to robot coordinate using the correlation between camera positions, robot position and monitor display. Four possible areas were tested to evaluate the performance of system. Robot coordinate of a target became the end-effector position and the joint angles were derived by inverse kinematics. The result shows that this system could reach all the targets well. Based on the result, this system successfully improved the flexibility of controlling robot with 3D movements. This ability increases the possibility to develop this system with some special task as picking and placing objects.

論文審査結果の要旨

本論文は EOG から目視点を算出し，その点まで 3 次元でロボットアーム先端を制御するシステム開発を試みたものである.

まず，垂直方向眼球運動測定用の Ch1 と水平方向眼球運動測定用の Ch2 の 2 つの電極を用いて EOG を計測し，両 Ch の EOG の積分値をヘルマート変換し，目視位置を算出した．また，電位の正のピーク値と負のピーク値の割合を比較し，閾値以上であれば随意性瞬目，それ以下であれば不随意性瞬目と判別をおこなった．次に、正面からアームが映るよう設置した Front Camera の映像をモニターに映し、モニター上の目標を目視し，アーム先端の(x,y,z)座標の内，x・z 座標を目標の座標と合わせ、次に随意性瞬目を行い，上方からアームが映るよう設置した Top Camera の映像に変え、その映像に映る目標を目視し，アーム先端の y 座標も目標に合わせることで，ロボットアームの 3 次元操作を行うことができることを実験により検証し、その有効性を確認した.

これらの研究知見は，学術上および産業技術への社会貢献に寄与できるものと判断し，よって本論文は博士（工学）の学術論文として価値のあるものと認める.

最終試験結果の要旨

学位論文を構成する学術論文として査読のあるジャーナルに 4 件, 学位論文の基礎となる学術論文に関する判定基準「学術論文が査読付き学会誌や論文集（Proceedings も含む。）に最低２編掲載されていること」を満たしており、博士後期課程学生としての必要な単位も修得し，平成２６年７月２２日に学位論文の内容を中心として，またこれに関した事項について諮問を行った結果，応答も的確であり、合格と認めた.

発表論文（論文名、著者、掲載誌名、巻号、ページ）

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