SEMGBased prediction of masticatory kinematics in rhythmic clenching movements

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ABSTRACT

This paper investigated the ability of a hybrid time-delayed artificial neural network (TDANN)/autoregressive TDANN (AR-TDANN) to predict clenching movements during mastication from surface electromyography (SEMG) signals. Actual jaw motions and SEMG signals from the masticatory muscles were recorded and used as output and input, respectively. Three separate TDANNs/AR-TDANNs were used to predict displacement (in terms of position/orientation), velocity, and acceleration. The optimal number of neurons in the hidden layer and total duration of delays were obtained for each TDANN/AR-TDANN and each subject through a genetic algorithm (GA). The kinematic modeling of a human-like masticatory robot, based on a 6-universal-prismatic-spherical parallel robot, is described. The structure and motion variables of the robot were determined. The closed-form solution of the inverse kinematic problem (IKP) of the robot was found by vector analysis. Thereafter, the framework for an EMG-based human mastication robot interface is explained. Predictions by AR-TDANN were superior to those by TDANN. SEMG signals from mastication muscles contained important information about the mandibular kinematic parameters. This information can be employed to develop control systems for rehabilitation robots. Thus, by predicting the subject's movement and solving the IKP, we provide applicable tools for EMG-based masticatory robot control.

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1. Introduction

The significance of the chewing process on digestion and health necessitates studies of the mastication system. Mastication in humans consists of two basic movements, clenching and grinding. For clenching, the mandible moves in the sagittal plane; for grinding, it traces a circular path in the frontal plane. More than 20 muscles are involved in the process of human mastication, with six of them playing the major role in mandible control during coordinated masticatory movements [40,45]. These muscles are the temporalis muscles, attached from the side of the skull to the top of the mandible; the masseter muscles, attached between the cheek and the lower rear section of the mandible; the medial pterygoid muscles, attached to the inside of the skull and the mandible; the lateral pterygoid muscles, horizontally attached between the skull and the mandible; and the digastric muscle, attached between the skull and the chin. The masseter and temporalis muscles are primarily employed during clenching, whereas the pterygoid muscles have their main role during grinding. During jaw closing, the mandible is elevated by the temporalis and masseter muscles, while it is protruded by the masseter muscles. Pterygoid muscles protrude the mandible, produce its side-to-side movements, and generate the grinding motion.

Researchers have utilized various methods to study the chewing process, including gnathosonics for measuring the sounds of mastication, ultra-high-speed cinematography for measuring mandibular movement and velocity, and laryngophone for monitoring swallowing [15]. Small markers or magnets have been used to record the chewing trajectory [43,17]. Electromyography (EMG) has been employed to study changes in the electrical activity of the muscles during mastication [15,36,26,20]. Changes in EMG parameters are better able to assess the sensory characteristics than mechanical measurements [15]. Experimentally obtained signals, together with the physiological cross-sectional area of the muscles, have been employed to estimate instantaneous muscle forces [4,31] or to differentiate food-texture characteristics [15].

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