Detection of Self-Stimulatory Behaviors of Children with Autism Using Wearable and Environmental Sensors

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Autism is one of the five pervasive development disorders that may cause severe impairment to a child. Depending on the degree of the symptoms, autism may cause severe impairments in one's social life such as social interaction and communication with other individuals. They may also face challenges in learning, concentrating, sensation and interacting with their surroundings. According to the Center for Disease Control (CDC), 1 in 150 8-year old children in many areas in the United States were diagnosed with autism. It is also known from recent studies that with early diagnosis we can intervene earlier which allows better assistance and treatment. Therefore, it is critical to have an objective assessment tool to assist diagnosis and for management. We have developed an affordable, reliable system that provides evidence based tools for assessment of children with autism. This system can detect various repetitive behavioral patterns often seen in children with autism and enables long term monitoring of repetitive behaviors. Therefore, it can be used to assist doctors, therapists, caregivers and parents with diagnosis and treatment of children with autism. This system incorporates 2 different sensor platforms which include environmental and wearable sensors. The system consists of a 3-axis accelerometer, small microcontroller and a Bluetooth module to transmit data to a base station such as a PC for analysis. We have customized this wearable device to integrate these modules which can be worn by a child. The environmental sensor configuration is composed of a microphone which records the acoustic data of the subject within the room. Using this sensor system, we are able to achieve the necessary information for assessment and therapy in autism research. We have analyzed the 3-axis accelerometer and acoustic data with an intelligent machine learning algorithm. The algorithm extracts time-domain and frequency domain features from the accelerometer data and applies statistical learning techniques to detect repetitive behavioral patterns. For acoustic data, we used sparse signal representation techniques to detect repetitive patterns that indicate vocalization behaviors. We have achieved an average of 89% in classification accuracy for detecting behavioral patterns. Based on the real data collected from children with autism, we were able to detect and recognize four self-stimulatory behaviors of children with autism. In one instance in which a subject had a tantrum, using the correlation between the hand flapping ratio and vocalization intensity, we were able to predict this extreme behavior. Our study opens an application in which devices could be used in a classroom environment to predict extreme behaviors in order that the stress of children with autism could be diverted accordingly so that their actions would be more socially agreeable.

Aiming a Surgical Laser With an Active Cannula

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An active cannula is a surgical device capable of dynamically changing its curved shape in response to rotation and translation of the several precurved, concentric, superelastic tubes from which it is made. As the tubes move with respect to one another in response to input motion at their bases (outside the patient), they elastically interact, causing one another to bend. This bending can be harnessed to direct the cannula through winding trajectories within the human body. An active cannula has the potential to perform a wide range of surgical tasks, and it is especially well suited for guiding and aiming an optical fiber (e.g. BeamPath from OmniGuide, Inc.) for laser ablation. Controlling the trajectory of the laser requires control of the shape of the active cannula, and in particular the position and orientation of its tip. Prior work has shown that beam mechanics can be used to describe the shape of the cannula, given the translations and axial angles of each tube base. Here, in order to aim the laser, we invert this relationship (obtaining the "inverse kinematic"), solving for the translations and axial angles of each tube, given a desired position and orientation of the cannula tip. Experimental evaluation of inverse kinematics was carried out using a prototype consisting of three tubes. The outermost tube is straight and rigid (stainless steel), with an outer diameter (OD) of 2.4 mm. The 1.8 mm OD middle tube is superelastic Nitinol, with a preshaped circular tip. The 1.4 mm OD innermost tube is Nitinol and is not precurved, representing the straight trajectory of a laser emanating from the tip of the cannula. We assessed the accuracy of the inverse kinematics by computing the necessary tube translations and rotations needed to direct the beam of the "laser" to sequential locations along a desired trajectory consisting of two line segments that meet at a corner. These inputs were then applied at tube bases to direct the laser to thirty points along the trajectory on a flat surface 100 mm away the cannula base. The position of the tip of the simulated laser was measured using an optical tracker (Micron Tracker H3-60, Claron, Inc.). Mean error between desired and actual positions was 3.1 mm (maximum 5.5 mm). This experiment demonstrates proof of concept for laser guidance, and establishes the accuracy of the inverse kinematic model. We note that these results are applicable to guidance of a wide range of medical devices in addition to lasers. Relevant references, as well as images of our prototype and experimental data described here can be found in an online version of this abstract at http://research.vuse.vanderbilt.edu/MEDLab/. This work was supported by NSF grant #0651803, and NIH grant #1R44CA134169-01A1.