Variable Self-Optimizing Cochlear Model for Heart Murmur Detection/Classification

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Accurate detection and classification of heart murmurs by auscultation is suboptimal and not always definitive. The murmur information perceived by the physician brain is the combined effect of both patient's (human) heart and the physician's ear. The information containing the murmur characterization which is retrieved by the human brain resides in the electrical signal coming out of the cochlea. For the very reasons described here, cochlea-like processing has been successfully applied to multiple speech recognition related technologies. This had not, before our prior work, been applied to human heart murmur analysis. Our prior research consisted of three steps: (1) capturing heart sounds, (2) processing the sounds using a cochlea-like filter, and then, (3) classifying each sound as being normal or a murmur using an artificial neural network (ANN). Previously in our research, we used a static cochlea-like filter model in step 2 as described above, which resulted a significant improvement in terms of accuracy of heart murmur classification. Our cochlear filter analysis helped identify information-rich frequency segments in human heart sound. We want to advance the cochlear filter model from a static to a variable frequency selective model with feedback from ANN for better optimization of the heart murmur classification. The heart sounds will be processed in ways more closely replicating the human cochlea than the static cochlear filter. A variable self optimizing cochlear filter will better reproduce the mechanism of the human cochlea in that it will contain a feedback system from ANN to cochlear processing to automatically select the most useful frequencies based upon a threshold mechanism filtering out those frequencies which do not contain significantly useful information about classification of heart murmur. The output of the sounds in the frequency range remaining (variable self-optimizing cochlear filtered sounds) may then be used by the neural network to make a final decision about murmur classification. Our hypothesis is that a variable self-optimizing cochlear filter will significantly improve the accuracy in classification of heart sounds as normal or murmur when compared to a static cochlear filter. Using this approach, we plan to develop an AI based system which will classify heart sounds with a success rate significantly better than the static cochlear filter previously developed.

Development of a Fiberoptic Distributive Shear/Pressure Sensor

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An estimate of $6 billion is being spent annually to deal with diabetes-related health problems. In the United States, 6% of the population (about 18 million people) has diabetes, either diagnosed or undiagnosed. During their lifetimes, about 15% of diabetic patients will develop a foot ulcer. More than 60,000 of them will end up with amputations of lower extremities due to complications arising from diabetes mellitus, accounting for nearly two-thirds of the total number of nontraumatic amputations performed annually. Previous studies report that has indicated that both the vertical and shear components of ground reaction force play a role in the formation of plantar ulcers. However, the exact relationship between stresses and ulcer formation is still unclear. The reason for that is due to lack of a sensor that is currently available to be able to measure pressure and shear force on the plantar surface simultaneously. It is because of these inadequacies that have motivated the search for a new design to transduce pressure and shear stress based on a multi-layered optical bend loss sensor. We have recently developed a sensor that can be used to measure shear and pressure of an extended area using fiber optic technology. The fiber optic technique that we have developed has also been extended by utilizing an array of microfabricated waveguides made of polydimethylsiloxane (PDMS). For the fiberoptic technique, the pressure/shear sensor consisted of an array of optical fibers lying in perpendicular rows and columns separated by elastomeric pads. A map of pressure and shear stress was constructed based on observed macro bending through the intensity attenuation from the physical deformation of two adjacent perpendicular fibers. Each sensing layer consists of multiple fibers molded into a thin PDMS substrate. In this design, the top layer is composed of a 3 by 3 fiber mesh with 9 intersection points and the bottom layer is made of a 4 by 4 fiber mesh with 16 intersection points. The space between the adjacent fibers is 0.5 cm. The pressured points between the top and the bottom layer are offset by 0.25 cm which is used to increase the shear sensitivity. In the experiment, the sensor was tested with various loading condition. A force image algorithm using neural networks was developed to identify the loading pattern, magnitude and direction of loads that were applied at more than one pressure point. Here 3 loading patterns with 5 different loading directions and 3 different loading magnitudes were tested. The results show a $>90\%$ accuracy was obtained using an algorithm with 2 layered neural networks system.