Shoulder Joint Clearance Detection for Astronaut Space Suits using Wearable Electromagnetic Resonant Spiral Proximity Sensor

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INTRODUCTION: Shoulder joint injury is a common musculoskeletal injury that occurs during astronaut training while they are wearing the space suit. There is restricted mobility around the shoulder joint due to the rigid inner components of the suit that constrains the desired range of motion for space mission tasks. This rigid piece of the suit is known as the hard upper torso (HUT), which allows for sealed connection between other components that sets upon the skin tight liquid cooling and ventilation garment (LCVG) that contains a tubing mechanics that keeps the body temperature regulated from reaching dangerous levels. During training sessions, astronauts can receive significant rotator cuff injuries from the lack of clearance between the LCVG and the HUT. A detection scheme that provides proximity, of a proposed minimum clearance distance of one centimeter to provide sufficient mobility, is lacking for space suit fitting.

PURPOSE: The objective of this paper is to propose a novel detection scheme using an electromagnetic resonant spiral sensor that allows for quantitative measurements of proximity between the shoulder joint with the LCVG and the aluminum component of the HUT.

METHODS: An LCVG model is created with net dressing and latex tubing in which the proximity sensor is placed upon. While water is continuously flowing through the tubing, a metal plate, which represents the scye bearing joint of the HUT, is placed in parallel to the sensor and measurements are increased every 0.5 mm until 10 mm is achieved. All 21 distances are measured in 20 separate repeated tests to run through a regression learning algorithm with half used to train and the other half to validate the response. Predictors were chosen based on the resonant frequency response with only the most parsimonious data chosen.

RESULTS: The results indicate that using a fine decision tree regression algorithm, the algorithm is able to validate the response with an RMSE of 0.93 mm with a strong coefficient of determination (R^2=0.93). This algorithm for this given scenario shows strong accuracy and repeatability for proximity detection up to 10 mm for reliable readings.

CONCLUSION: This study presents a novel method of identifying proximity detection using an electromagnetic resonant spiral sensor for space suit fitting application. Using this knowledge will allow for future implementation into the space suit for quantitative fitting parameters to help adjust and avoid potential musculoskeletal shoulder joint injuries.