Abstract

This dissertation presents the fundamental knowledge in developing a tactile sensor by mimicking the epidermal ridges structure of human, capable of precise force detection and sensitivity enhancement. This study discussed the tactile perception of human and, in particular, it focused on the features of epidermal ridges and Meissner corpuscles of human fingertip skin. The study developed a micro-scale tactile sensor mainly comprising of elastic materials with a ridge-structure surface and an array of strain gauges below the edges of ridges. With the proposed tactile sensor, the sensitivity enhancement was investigated in force detection and deduced the optimal structure of the artificial epidermal ridges theoretically and experimentally. By conducting series of finite element method (FEM) simulations and experiments, this study confirmed that the ridge structure has an effect on either static or kinesthetic tactile sensing of the proposed sensor. Mimicking the features of epidermal ridge by the elastic material – polydimethyl siloxane, the width of which is 400 μm, the ridge with height of 160 μm is optimal for shear force detection but to experience less pressure for a stable output, while the ridge with height of 110 μm is optimal for normal force detection. Furthermore, with the proposed tactile sensor, the texture information, such as softness and roughness, could also be obtained to realize multi-functions.

Chapter 1 describes the motivation, the literature review of tactile sensors, original contributions and outlines of this study.

Chapter 2 describes the background knowledge including functions of human tactile perception, mechanoreceptors, and the state of the art in biomimetic tactile sensors. Also our previous work on a macro-scale texture sensor, which was inspired by human finger, for texture and lump detection is discussed to show the benefits of the biomimetic texture sensor with epidermal ridges.

Chapter 3 describes the design concept. Materials are investigated to benefit tactile sensing applications. Microfabrication processes are discussed to manufacture the elastic material and the strain gauges. The feasible fabrication process of the tactile sensor is determined.

Chapter 4 confirms the design of the tactile sensor in detail based on theoretical calculation

and FEM analysis to obtain an optimal ridge structure by conducting the simulation on normal force and shear force detection. When the ridge width is 400 μm, which is a typical width of the ridges of human fingers, the ridge height of 160 μm is optimal for shear force detection but to experience less pressure for a stable output, while the ridge height of 110 μm is optimal for normal force detection.

Chapter 5 describes the evaluating experiments and analyses of the results. The experimental setup and results including normal force and shear force detection are discussed. As the applications of the proposed tactile sensor, texture detection including softness and roughness is conducted and discussed.

Chapter 6 summarizes this study and discusses future research prospects.