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Force-feedback System with Integrated CMOS Micromachined Tactile Sensor

超微型單晶片壓力感測與力回饋系統設計

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作品摘要

微創手術的發展開創了歷史新頁，借由進入身體的機械手臂來取代大傷口的手術，不論已經被廣泛使用的腹腔鏡系統或者是使用了尖端科技的達文西系統，目前微創手術中所用的夾具當中都沒有裝置壓力感測系統，在醫生對於器具夾力的控制只能憑著經驗以及不斷地重覆練習來達成，無疑是一項艱鉅的挑戰。

本設計作品之理念是希望可以透過晶片設計的技術，搭配現有的力回饋操作介面技術來完成一套具備精密力回饋功能的微創手術操作系統，讓醫師們在使用精密夾具時，有一個真正觸摸到病患器官的觸感，大幅提升醫師對於手術過程中的掌握度、減輕手術技術上的負擔。

在設計當中，最重要的關鍵技術是高靈敏度的壓力感測器電路，使用本團隊已發表的感測器與電路整合技術，可以實現出一個3.26mV/μN靈敏度的單晶片，將壓力的類比電壓資訊傳出至控制端以後，結合現行已經非常成熟的力回饋技術，完成整個系統的設計，未來更進一步加入無線傳輸系統，精密遠距手術的實現將不再是夢想。

The minimally invasive surgery (MIS) has been rapidly developing nowadays for its small cut, less pain and less recovery time. A magnetic hydrogel-based microgripper for intravascular applications was developed. When the surgery devices grasp human tissues or organs, the applied stress has to be well controlled. To avoid excessive stress, real time monitoring of the stress is essential. Triaxial micro-electro mechanical systems (MEMS) tactile sensors were attached to the tip of a forceps for measuring the pressure and shear stresses. The tactile sensors can detect the grasping force and two directional shear stresses at the same time. When a user-defined motion is performed, the integrated MEMS tactile sensor and readout circuit transforms the pressure into the electrical signals. The analog-to-digital converter (ADC) converts the electrical signal into digital data, and the signal processing block generates a control signal for generating the feedback force to control unit. The feedback force can provide information of mechanical grabbing force to user, so user can apply a proper grasping force during the surgery.

In this force-feedback system, tactile sensor is integrated with sensing circuit on single chip. To improve sensitivity, a T-shape protrusion architecture is involved. Also, to simplified the post-process of the sensor, the layout of the chip is designed to be manufactured by single-step wet etching. A set of fully differential correlated double sampling capacitor-to-voltage converter circuit with switching capacitor array and calibration scheme is used as sensing circuit. The compensation for process and environment variations is considered within circuit design.

In this design, the feedback force to user is generated by a balloon tactile actuator system. Several tiny balloons are placed under the control buttons. After the feedback system receiving signal generated by the tactile sensor, it will generate feedback force through balloon tactile actuator system to user. When the force in the tip of forceps is increasing, an air compressor blows the balloons according to the force signal from the feedback system. By the combination of the tactile sensor and the balloon tactile actuator system, the force-feedback system can be realized.

In near future, the force-feedback system can be applied to the concept of Internet of things. This system can be applied to any accident scene through the combination with wireless communication systems. Through remote control systems, a doctor at office can take care of patients immediately after ambulance arrives at the accident scene. This will cut down the waiting time of patients to medical care and the raise possibility of surviving. Through the application of remote surgery, lots of tragedies can be stopped in time.

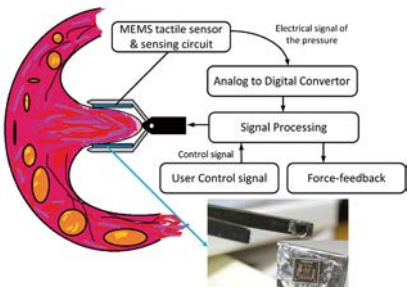

圖 1 / 超微型單晶片壓力感測與力回饋系統圖
System Block Diagram of Force-feedback System with Integrated CMOS Micromac Hined Tactile Sensor