追新刺骨-應用於骨科手術導航之多目標三維定位系統 | The 3D Multi-Target Detection System for Orthopedic Surgery Navigation Application

APPLICATION GROUP A19-074

隊伍名稱 無線視界
Wireless Vision

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研究領域
第五代行動通訊系統、Beamforming 陣列射頻收發系統、室內定位、心肺生醫雷達等技術。

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研究領域
微波 / 毫米波天線及相關電路與系統之設計。

作品簡介

微創手術具有傷口小、恢復快等優點，是目前多數患者在手術上的優先選擇。在骨科手術中，微創手術常用於脊椎與關節部位。其中脊椎具有支撐人體軀幹與保護脊髓等重要功能。在手術過程中，數毫米的誤差就有可能傷害患者的脊隨神經，甚至使病患永久癱瘓，可以說是差之毫釐，失之千里。為此，手術導航系統的使用需求就應運而生。導航系統有如 GPS 定位系統般，在手術過程中，即時地追蹤手術器械與固定於脊椎上的定位標籤，協助醫師完成更為精準的微創手術。

本作品以微波雷達技術為基礎，開發一套可應用於骨科微創手術之三維追蹤定位系統。微波追蹤技術具有多目標追蹤、抗光線干擾、定位標體積小等優點。本系統使用連續波雷達，操作於免授權 24-GHz 頻段，以相位追蹤累積技術克服連續波雷達之相位歧異區，達成大於半波長的位移追蹤範圍。定位標使用二位元相位調變，使其具有可識別性，同時可對抗環境多重路徑反射干擾。系統基頻端使用鑑頻器分離、解調不同定位標的回波訊號，以達成多目標定位。解調後的訊號透過資料擷取卡將類比訊號轉換為數位訊號並進入電腦端運算。使用 4 組雷達收發機測得定位標距離，再透過三角定位法即可計算定位標的空間座標。本研究已完成單、雙定位標的三維定位，根據實驗結果，在1.2公尺的距離下，三維最大誤差小於 1.8 mm。

在系統設計中，可同時偵測數十個具有不同調變頻率的定位標籤。未來除了可以定位器械的位置、姿態，還可以同時定位多組脊椎節，提供更完整的手術資訊。目前此系統正在朝向商品化發展，預計在不久的將來能為醫療與人類健康貢獻一份力量。

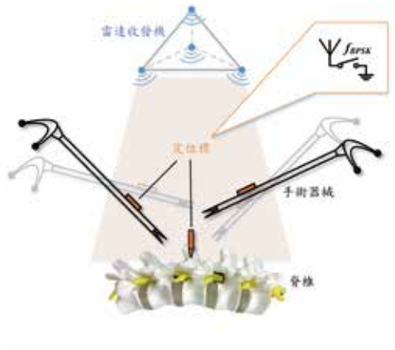

圖 1. 應用於微創手術之微波追蹤系統示意圖

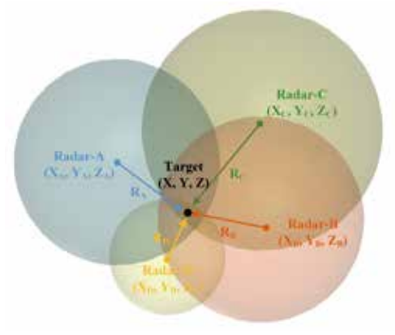

圖 2. 三維空間三角定位法

ABSTRACT

The minimally invasive surgery (MIS) has the advantage of small incision, and Short Hospital Stay. It becomes most patients' prior choice in recent years. However, the minimally invasive spine surgery has high risk of spinal cord damage and even cause paraplegia. To further improve the features of MIS, the surgery navigation system comes into being. The navigation system plays a role as a global positioning system (GPS) inside a surgical room. It guides the direction and cooperates with the surgeon for precise operation. The proposed system has the ability of tracking multiple targets mounted on the spine and surgical instruments instantly. A more practical navigation system is developed for the achievement of minimally invasive spine surgery.

In this work, a three-dimension (3D) tracking system based on microwave radar technique is designed and implemented for minimally invasive orthopedic surgery application.
Microwave tracking system has the advantage of multi-targets detection ability, anti-light interference, and small-sized transponder. The proposed system is using acontinuous-wave (CW) radar which is operating at unlicensed 24 GHz. The phase tracking and accumulated method is adopted to overcome the phase ambiguity in CW radar. The binary phase-shift keying is applied on the transponder to provide identification, and it also can isolate the multi-path reflection interference. In thebaseband of proposed system, a frequency discriminator is designed to separate and demodulate the backscattered signal from different transponder, and it makes the radar system has the ability of multi-target detection. The demodulated signal is acquired by an analog-to-digital converter and processed in a computer.
Four distances are measured by four radars located in the 3D space. The coordinate of transponder is calculated from the triangulation theory.

The experiments of one target and two targets tracking have been achieved. According to the measured results, the 3D positioning error is less than 1.8 mm in the distance of 1.2 m.

In the design concept of proposed system, dozens of transponder with different modulation frequency can be identified and tracked at the same time. With this feature, the navigation system also has the potential on orientation detection and multiple vertebra tracking. Therefore, more detailed information will be presented to assist MIS. The system is walking on the way for commercialized. It will provide contribution on medical treatment and people's health.

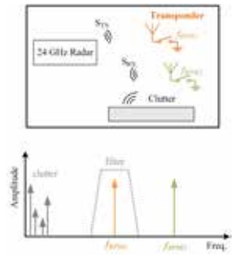

Fig.3 The operation theory of multi-target identification

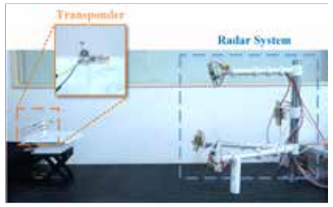

Fig.4 The Experiment setup of 3D microwave tracking system