OPTICAL GONIOMETER DEVICE FOR CONTINUOUS MONITORING OF THE KNEE MOVEMENT IN PHYSIOTHERAPY APPLICATION

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DOCTOR OF PHILOSOPHY

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SUPERVISOR's DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRACT

Knee joint is the most crucial among the lower limbs joints due to its exposed location and its major role which carries the entire burden of the body practically our entire life. Hence, by being able to measure the knee joint angle accurately during continuous movement, allows the physiotherapist to detect knee joint damage at early stages before it turns into an injury or permanent scar tissue. Due to the limited number of continuous monitoring devices applicable for diagnosis and treatment stage of the knee, most physicians opted for X-ray and magnetic resonance imaging (MRI) technologies to have some insight on the knee issue before suitable treatment can be recommended. Aside from being expensive for general use of MRI, X-ray on the other hand can cause short-term side effects due to radiation exposure. Knee joint angle measurement devices technologies include but are not limited to the implementation of accelerometer, electrogoniometer, torsiometer, acoustic, visual sensory, and optic fibre. There are many limitations to these technologies that require improvements before they can become clinically applicable such as accuracy issues, limited range of motion measurement, and inability to monitor continuous movement measurement of the knee joint, which have been discussed thoroughly in this research. The need for technologies with higher accuracy, reliability, able to measure the full knee range of motion, applicable for continuous motion measurement and lower cost have always been a crucial factor. The use of optical based devices provides significant contribution in this area due to their advantages such as immunity to electromagnetic interference, lightweight and possibly small sensor setup. However, the application of intensity-based optical fibre sensor for human joint motion detection resulted in limited detection angle, where most sensor are not able to detect angle variation of more than 90^{o}. To improve this limitation, an optical sensor approach with mechanical-assisted components assembly that translates angular movement to linear movement was developed. The light detection on the photodiode array sensor at different pixels is analysed to represent the angle movement of the knee. The sensor is securely attached to a medical standard knee brace tool to ensure firm sensor placement on the knee area. Based on current study, the proposed optical sensor has a range of motion between 0 to 160^{o}, with 0.08^{o} resolution, has a 210.5 sampling rate per second, which allows it to present and record a real time graphical output to demonstrate the knee joint activity performance. Moreover, the proposed device was able to give an excellent internal consistency obtained by Cronbach's Alpha analysis of 0.967, and has 98.044% correlation with the gold standard goniometer.

ABSTRAK

Sendi lutut adalah yang terpenting di kalangan sendi anggota bawah badan oleh kerana lokasinya yang terdedah dan peranan utamanya yang menampung seluruh beban badan sepanjang hayat kami. Oleh itu, dengan dapat mengukur sudut sendi lutut dengan tepat semasa pergerakan berterusan, akan membolehkan ahli fisioterapi mengesan masalah sendi lutut pada peringkat awal sebelum ia bertukar menjadi kecederaan atau tisu parut kekal. Disebabkan pilihan peralatan pemantauan yang terhad yang boleh digunakan untuk peringkat diagnosis dan rawatan lutut, kebanyakan pakar perubatan memilih teknologi X-ray dan pengimejan resonans magnetik (MRI) untuk mendapatkan sedikit pandangan tentang isu lutut sebelum rawatan yang sesuai boleh disyorkan. Selain teknologi MRI mahal untuk kegunaan umum, X-ray sebaliknya boleh menyebabkan kesan sampingan jangka pendek akibat pendedahan radiasi. Teknologi peranti pengukuran sudut sendi lutut termasuk tetapi tidak terhad kepada pelaksanaan accelerometer, elektrogoniometer, torsiometer, akustik, sensor visual dan gentian optik. Terdapat banyak limitasi kepada teknologi ini yang memerlukan penambahbaikan sebelum ia boleh digunakan secara klinikal seperti isu ketepatan, julat pengukuran pergerakan terhad dan ketidakupayaan untuk memantau pengukuran pergerakan berterusan sendi lutut, yang telah dibincangkan secara menyeluruh dalam penyelidikan ini. Keperluan untuk teknologi dengan ketepatan yang lebih tinggi, kebolehpercayaan, mampu mengukur julat gerakan lutut penuh, sesuai untuk pengukuran gerakan berterusan dan kos yang lebih rendah sentiasa menjadi faktor penting. Penggunaan peranti berasaskan optik memberikan sumbangan besar dalam bidang ini kerana kelebihannya seperti imuniti terhadap gangguan elektromagnet, ringan dan kebarangkalian tetapan sensor yang lebih kecil. Walau bagaimanapun, aplikasi penderia gentian optik berasaskan intensiti untuk pengesanan gerakan sendi manusia menghasilkan sudut pengesanan terhad, di mana kebanyakan penderia tidak dapat mengesan lebih daripada 90^{o}. Untuk menambah baik had ini, pendekatan penderia optik dengan pemasangan komponen bantuan mekanikal yang menterjemahkan pergerakan sudut kepada pergerakan linear telah dihasilkan. Pengesanan cahaya pada sensor linear array fotodiod pada piksel yang berbeza dianalisis untuk mewakili pergerakan sudut lutut. Sensor dipasang pada alat pendakap lutut kelas perubatan untuk memastikan peletakan sensor yang kukuh pada kawasan lutut. Berdasarkan kajian semasa, penderia optik yang dicadangkan mempunyai julat pergerakan antara 0 hingga 160^{o}, dengan resolusi 0.08^{o}, mempunyai kadar pensampelan 210.5 sesaat, yang membolehkan alatan ini membentangkan dan merekodkan hasil grafik masa nyata untuk menunjukkan prestasi aktiviti sendi lutut. Dengan mengunakan alatan yang dicadangkan, ketekalan dalaman yang sangat baik dapat diperolehi oleh analisis Alpha Cronbach sebanyak 0.967, dan mempunyai korelasi 98.044% dengan goniometer standard emas.

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