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An evaluation of contactless thermal sensing elements for use in a technology based diabetic foot disease detection solution

Joseph Rafferty, Ian Cleland, Chris Nugent, Ken Armstrong, Godfrey Madill

Abstract— Global incidence of diabetes is rising. If not properly managed and treated, diabetes can lead to serious complications, notably amputations, due to Diabetic Foot Disease (DFD). Amputations from DFD can be reduced through monitoring/analysis. This study evaluates a number of sensing elements to enable a novel monitoring/analysis platform for the purposes of assessment of DFD.

I. INTRODUCTION AND RELATED WORK

In recent years there has been a global obesity epidemic. Associated with this is an increase in the number of diagnosed cases of diabetes [1]. If diabetes is mismanaged, serious complications can occur including the need for amputation. It is estimated that globally, due to diabetes, a limb is lost every 30 seconds [1]. Informed self-management of this condition increases care reducing amputations [2]. In the case of Diabetic Foot Disease (DFD) indicative precursors to amputation include development of ulcers and reduction in blood circulation. Current works [1–3] have successfully detected these precursors using thermal information about the foot. These approaches use a number of sensing elements ranging from contact Skin Temperature Probes (STP), IR thermometers (IRT) and thermal vision camera systems [1–3].

STPs provide an accurate way to gauge foot temperature with some caveats. STPs are disposable so have a recurring cost, physical contact may encourage disease or infection and the sensors require placement on specific points on the foot to generate useful readings. Similarly, IRTs have issues related to requiring specific sampling points. Finally, use of point sampling captures limited information, reducing diagnostic potential.

Thermal vision camera solutions have been used with promising results [3]. These collect high resolution temperature data about the entire foot. Current thermal camera solutions are expensive, requiring a specific controlled environment and do not incorporate automated analysis.

To address these deficiencies, the authors propose the use of low cost simple thermal sensing elements used within a diagnostic solution. This approach enables low cost monitoring through the use of contactless sensors. This would increase sampling frequency, reusability and lower the barrier to data capture. This solution could additionally provide condition management in conjunction with offline, local and remote analysis.

In order to achieve this, a number of sensing elements need to first be evaluated for their suitability, as determined by accuracy and Reading Attenuation (RA). RA is important as this solution may not operate at a fixed distance, however, will

guide alignment through a user interface. An evaluation of these sensing elements is presented in Section II.

II. EVALUATION OF THERMAL SENSING ELEMENTS

A number of sensing elements have been evaluated to compare accuracy in relation to medical grade contact sensor and an IR sensor, as used in current DFD analysis.

The sensing elements tested are cost effective, reusable, contactless and may operate with the solution to enable production of this management platform.

Sensors evaluated were a Texas Instruments SensorTag, a FLIR ONE, a Heimann HTPA, a Seek and an IRT. All these devices, except the IRT, can be easily integrated into a diagnostic solution. SensorTags are small modules that can sample emissive temperature through use of a directional IR thermopile. The FLIR One and Seek are consumer-grade thermal vision cameras. The HTPA is an industrial-grade thermal vision sensor. The IRT is akin to those used in DFD detection. These sensors were tested against the ground truth data provided by the STP (Philips, 21091A). Table I presents the results of this comparison, throughout a range of distances.

TABLE I. A COMPARISON OF THE ACCURACY OF A NUMBER OF THERMAL SENSING ELEMENTS AT A RANGE OF DISTANCES

Sensor	Negative deviation (c) at sensing element distance (cm)									
	1 cm	5 cm	10 cm	15 cm	20 cm	25 cm	30 cm	35 cm	40 cm	45 cm
Sensor Tag	13.4c	16.12c	17.58c	17.37c	17.37c	16.67c	18.17c	18.07c	18.28c	18.5c
FLIR One	4.0c	5.1c	5.29c	4.5c	4.79c	5.07c	5.74c	5.47c	5.37c	5.58c
SEEK	7.31c	9.50c	8.31c	8.59c	8.68c	9.50c	9.22c	10.13c	10.40c	11.31c
HTPA	8.86c	9.09c	8.91c	9.10c	9.10c	9.32c	10.27c	10.28c	10.47c	10.86c
IRT	7.31c	7.59c	7.68c	7.40c	7.97c	8.46c	9.04c	9.15c	9.08c	9.26c

In evaluating these sensors, two factors will be considered, deviation and RA. Deviation of readings should remain within the range set by the STP and IRT as these are two accepted sensing elements for this application. Only the FLIR one meets this criterion. RA is determined by evaluating the range of temperatures from the 1cm and 45cm readings. Elements that express better RA than the IRT will be considered, these are FLIR one and the HTPA.

Through this evaluation it is apparent that the FLIR one should be adopted for a DFD analysis platform due to it having the higher accuracy and less attenuation than all other evaluated contactless sensing elements.

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