

Tactile Terrain Classification Technique for Legged Robots

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I. MOTIVATION

Biological systems perceive their environment through senses such as visual observation, touch sensing, odor recognition, and hearing perception. Since legged robots are characterized by intermittent ground contacts, it seems natural to investigate what information can be gained from these repetitive tactile events. In particular, we ask whether through tactile sensing only, can a legged robotic system recognize and classify their operating environment. To investigate this question, we utilize a high density tactile pressure sensor array consisting of 1936 individual sensors arranged in a grid covering 55.88 mm² in area, to measure unique pressure distribution profiles of a variety of terrains. Using classification algorithm techniques, these unique pressure distribution profiles are categorized into a library for use online. With this library, the legged system will be able to identify their operating terrain, and adapt their control system to deal with these environmental changes, thus providing a more robust adaptable autonomous controller.

II. STATE OF THE ART

To date terrain classification through touch (using proprioceptive sensors) has been implemented on wheeled autonomous robots [1]. These techniques most often utilize the vibration signatures induced by the terrain interaction, which have been shown to exhibit terrain signatures in the frequency domain [2]. Vibrational terrain classification may not work well on legged robots due to the natural vibrations exhibited by these devices interfering with the vibration profiles. However, a pressure sensitive skin is well suited for terrain classification on legged robots because the pressure profile of each terrain is expected to be unique.

Previous robot skin research has created skin coverings for robot mechanisms, which are used for collision detection [3], [4], [5]. The various sensors used to cover robot mechanisms, are pressure sensor arrays containing a multitude of individual pressure sensors of various types including but not limited to capacitance and piezoresistive based sensors. Our research differs from previous robotic skin research in that we are not designing and manufacturing our own pressure sensors. Instead, we are using an off-the-shelf commercial pressure sensor, and applying the sensor technology to fit our needs of terrain classification.

III. OUR APPROACH

A biological organisms sense of touch is based on interpretation of signals sent to the brain from pressure sensitive nerves within the organisms skin [6]. We utilized the Tekscan© I-Scan© piezoresistive-based pressure sensor system with the #5051 sensor map featured in Fig. 1(a), to emulate this biological process. The sensor is manufactured from flexible polyester, is only 0.1 mm thick, and can conform to different curvatures without affecting the sensors digital output. The Tekscan© Evolution© handle, also seen in Fig. 1(a), transfers the digital output pressure distribution data from the sensor array at a frame rate of 100 Hz to a computer for recording. Data is saved to a .txt file as individual 44 x 44 matrices with 8 bit integer matrix elements. In this work, we describe the design and use of a Pressure Sensitive Robot Skin (PreSRS) that uses this sensor to ID terrains based on foot contact.

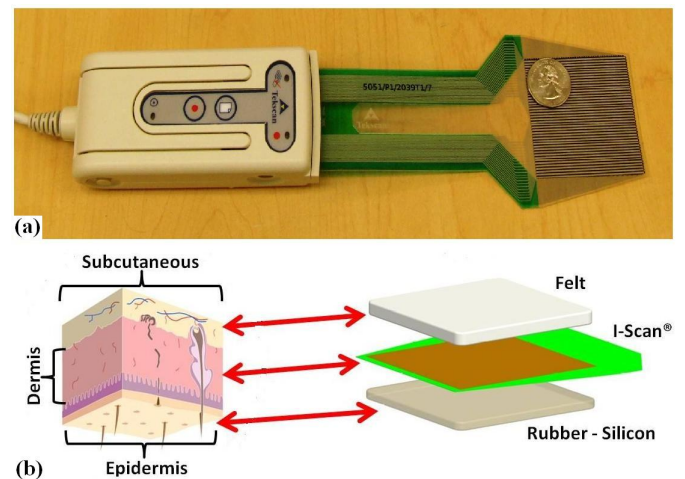


Fig. 1. (a) the I-Scan© pressure sensor array with a U.S. quarter for size comparison, (b) the correlation between the design of PreSRS and human skin.

Fig. 1(b) depicts a comparison of a human skin and our PreSRS system. The subcutaneous layer of skin (the fat layer) under the heel bone conforms the skin to uneven terrains, thus allowing many of the pressure sensitive nerves in the skin to contact with the terrain [6]. This is replicated

on PreSRS using a soft woolen felt material 5mm thick. The dermis layer of human skin (the middle layer), contains the numerous pressure sensitive nerves, which are mimicked by the multiple individual pressure sensors on the I-Scan[®] sensor array. An outer layer of hard rubber, as in the humans epidermis layer of skin (the outer layer), is needed to protect the sensors from the highly uneven loads applied during experimentation.

Before PreSRS is implanted onto a legged robot, it was placed on the bottom of a human foot in order to quickly evaluate the efficiency of terrain classification using pressure distribution profiles. In total six terrains were tested, shown in Fig. 2 along with the resulting terrains pressure distribution profiles.

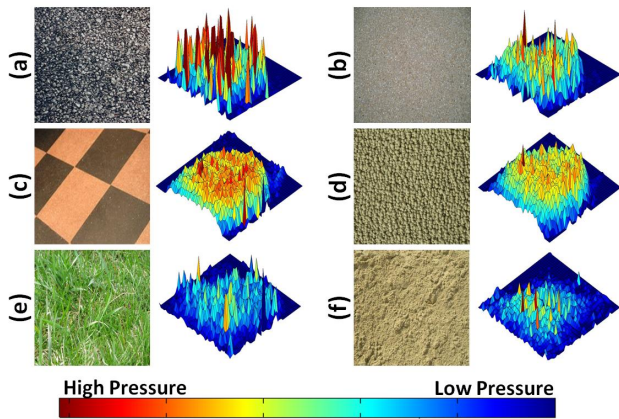


Fig. 2. The six different terrains PreSRS was tested on including (a) asphalt, (b) concrete, (c) tile, (d) carpet, (e) grass, and (f) sand. Adjacent to each terrain image is the pressure distribution profile recorded by PreSRS, the dimensions are 55.88 mm²

Terrain classification results are obtained by inputting the magnitude of the one-dimensional Fourier transform, calculated from the pressure distribution profiles, into a Parzen Window Estimator algorithm. One hundred samples under three different speeds for each terrain were recorded for training and 25 samples under the same three speeds were used in testing the trainers accuracy. Initial classification accuracy results are depicted in Table 1. in a confusion matrix.

Table 1.

		Trained					
		Asph.	Con.	Tile	Carpet	Grass	Sand
Tested	Asph.	98.3 %	1.67 %				1.67 %
	Con.	1.67 %	98.3 %	100 %			
	Tile				1.67 %		
	Carpet				98.3 %		
	Grass					100 %	
	Sand						98.3 %

Fig. 3.

As seen in the above table, the ability of PreSRS and our classification identification system to distinguish between multiple terrains shows great promise. In the future, we will test how well this system works on a legged robot and

investigate what other locomotively relevant information can be attained from these sensors.

IV. OPEN QUESTIONS

How an adaptable controller for leg gaits will increase the performance and stability of legged robots.

Possible obstacles to expect when adapting our robot skin PreSRS to an actual legged robot.

What other uses can the pressure profile of a given terrain yield.

V. FORMAT

We plan to display our research with a poster presentation.

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