SkinBot: A Wearable Skin Climbing Robot

Artem Dementyev
MIT Media Lab
Cambridge, MA
artemd@mit.edu

Javier Hernandez
MIT Media Lab
Cambridge, MA
javierhr@mit.edu

Sean Follmer
Stanford
Stanford, CA
sfollmer@stanford.edu

Inrak Choi
Stanford
Stanford, CA
irchoi@stanford.edu

Joseph Paradiso
MIT Media Lab
Cambridge, MA
joep@mit.edu

ABSTRACT
We introduce SkinBot; a lightweight robot that moves over the skin surface with a two-legged suction-based locomotion mechanism and that captures a wide range of body parameters with an exchangeable multipurpose sensing module. We believe that robots that live on our skin such as SkinBot will enable a more systematic study of the human body and will offer great opportunities to advance many areas such as telemedicine, human-computer interfaces, body care, and fashion.

Author Keywords
Skin, robotics, wearable devices, telemedicine

ACM Classification Keywords
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INTRODUCTION
Semi-autonomous robots have become a critical tool for the systematic exploration of challenging scenarios such as the rubble of natural disasters, the bottom of the oceans, or distant planets such as Mars. With a similar philosophy in mind but a significant difference in scale, this work proposes using wearable robots to systematically explore the human body.

While there is a large array of instruments and wearables to capture different aspects of the body (e.g., physiology, behavior), many of the devices still require the direct manipulation of an expert practitioner, are usually designed to remain at a specific body location (e.g., chest, wrist), and/or do not have direct access to the skin. To help address these limitations, this work leverages the benefits of such instruments with robotics. In particular, we propose and develop SkinBot; a small wearable semi-autonomous robot that lives on the skin surface and provides objective and systematic digitization of the body. To successfully achieve these goals, SkinBot and similar robots need to satisfy several design considerations such as (1) being lightweight and small, (2) have the ability to move and adhere to the skin, (3) have multimodal sensing and actuation capabilities, and (4) have the ability to communicate with a central control unit or other robots to achieve complex tasks. To the best of our knowledge, this is the first work to show a functional wearable robot that meets the previous design considerations.

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PREVIOUS WORK
Developing a small robot that can adhere and move over the skin surface is challenging due to many factors such as the elasticity of the skin and many of its irregularities (e.g., wrinkles, hair). Moreover, the robot needs to be able to adhere irrespective of its orientation and multiple directions of gravitational forces. Existing approaches have devised successful mechanisms for climbing vertical surfaces, such as magnetic wheels and gecko-like adhesives and suction [2, 4, 6, 8, 10], and other studies have explored cloth-climbing robots using fabric pinching [3, 9] and magnetic rollers or needles for adhesion [1, 5]. However, such approaches cannot be easily used on the human skin due to their large size and/or incompatible adhesion methods. In contrast, this work proposes a robot that circumvents many of the previous challenges.

SKINBOT DESIGN
With an iterative design process, we designed and developed SkinBot which consists of two main parts: a 2-legged suction-based locomotion system, and an exchangeable multipurpose sensing module.

Locomotion. To move over the skin surface, we use a suction-based approach which outperformed other considered methods (e.g., sticky pre-gelled wheels, pinching on the clothes) by covering a larger proportion of the body and better adapting to some of the skin challenges. In particular, we used an in-house 3D printer (Form 2, Formlabs, Grey resin) to fabricate the suction cups and other custom parts. We added a pressure sensor to each of the cups to detect if the suction cup was or not attached to the skin. The whole locomotion process is controlled by a 21-state machine implemented on a microcontroller. Four micro servo motors (two for each leg)

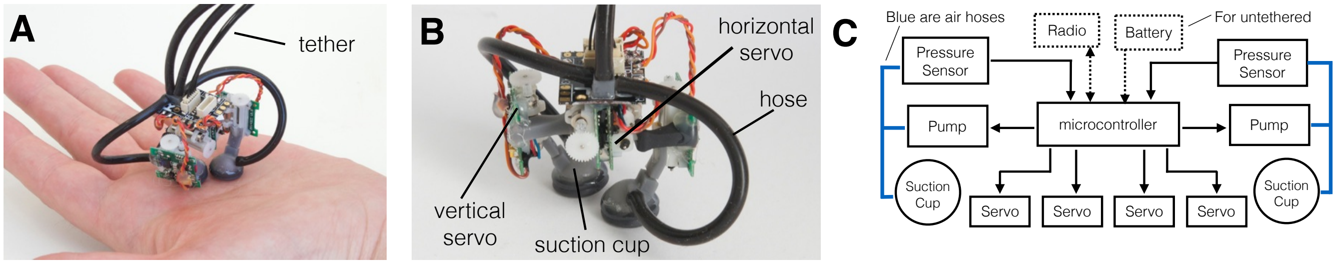

Figure 1. A) SkinBot attached on the surface of the skin, B) close-up image, and C) system diagram of its main components.

and two vacuum pumps were used for movement. Figure 1 shows SkinBot and some of its components.

Sensing. To capture as many body parameters as possible, we developed an exchangeable multipurpose sensing module that can be easily replaced depending on different applications. In particular, we created several modules containing a 3-axis accelerometer, a skin-facing RGB camera, and a magnet-based grip to allow the attachment of other existing biosensors. To help expand the sensing capabilities, the cups were modified to serve as electrodes and capture the electrical properties of the body such as electrodermal activity from the wrist or electrocardiograms from the chest.

APPLICATIONS

Some of the potential areas are as follows:

Telemedicine. As the main motivational use-case scenario for SkinBot, the modules we have developed contain several sensors that can help provide remote and objective access to the body and several of the parameters that are relevant for clinical assessment. For instance, the motion sensors are used to capture subtle cardiac and respiratory motions from the chest [7] and the skin-facing camera is used to take photos of skin anomalies such as moles or warts.

Activity Tracking. Traditional wearable devices are designed to be worn at a specific location from which they can provide a set of metrics. By being able to move over the skin, the wearable can provide and expanded set of metrics depending on its location and time of the day. For instance, SkinBot can move to the back to monitor body posture when sitting down, move to the waist to track steps when walking, and/or move to the chest to monitor respiratory signals during sleep.

Body Care. Different modules could also be developed to promote long-term care and maintenance of the body. For instance, one module could be used to monitor skin hydration and apply body lotion when needed, and another module could be used to detect and shave excessive hair.

Fashion. SkinBot could also be used as a self-expression tool to change the appearance of the body. For instance, a module could be designed to make tattoos or apply makeup on the skin, and the robot itself could be used as a garment.

CONCLUSIONS

This work demonstrates the first wearable robot with the ability to move over the surface of the skin and capture a large range of body parameters. Beyond medicine, the proposed robot could be used in other settings such as body care and fashion. In the future, we expect swarms of this kind of robots to become our intimate companions and assist us in daily life.

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