HapticPole: Running Navigation Through Skin Drag and Shape Change

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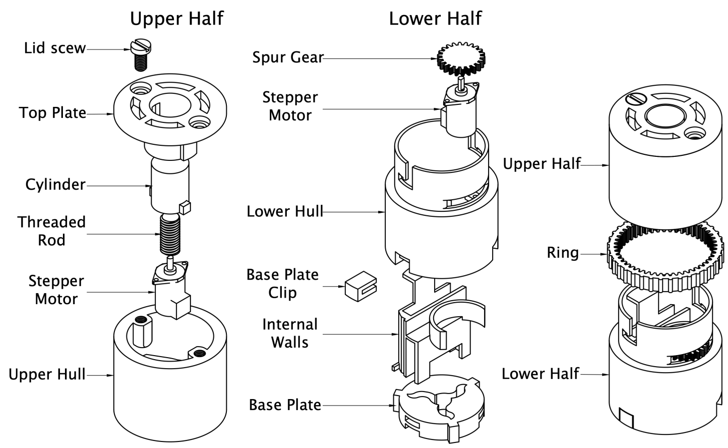

Figure 1: HapticPole as exploded view: divided into upper half (left) and lower half (middle) separated by the rotating ring.

ABSTRACT

Trail running is a challenging type of running on unpaved ground, including rocks, pebbles, and dirt with elevation changes, that is becoming ever more popular. Trail runners encounter risks of falling, rely on more muscle groups to balance, and require awareness and attention to foot placement. Current navigational aids take their eyes away from the trail, forcing them to stop to read a map, or occupy the auditory channel, which could otherwise act as an important mode of hazard detection outside the field of view. We propose HapticPole, a prototype that is designed to transmit information through shape change and skindrag. The 3D printed prototype performs a set of tactile interaction patterns for navigational instructions as will be defined in an elicitation study.

CCS CONCEPTS

• **Human-centered computing → Haptic devices**; **Empirical studies in HCI**.

KEYWORDS

navigation for trail running, tactile feedback, skin drag, shape change

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1 INTRODUCTION

Trail running can be described as running over trails, i.e. running on soft surfaces like grass, dirt, broken rocks, pebbles and many more. Often trails contain large altitude differences, which makes trail running more challenging than, e.g., running on a track around a sports field. Many trail runners also use special shoes that protect them against sharp rocks and grant additional stability. Compared to traditional running, by trailrunning, athletes strengthen their stability and balancing skills while also improving their coordination and reactivity. Moreover, the softer ground in trail running compared to urban running reduces impact stress and preserves the joints of the runner. Depending on the terrain, trail running can have a high risk of injury. Roots, loose rocks, branches, ditches and proliferating undergrowth may impede the runner and cause tripping or slipping. Such additional obstacles, as well as the ever-changing terrain, necessitate much more focus and a carefully chosen foot placement. This is why, especially, tackling "technical trails require(s) a lot

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Figure 2: Grip of the HapticPole

more attention " [1]. It is also one of the reasons why many professional trail runners rely on trekking poles for additional balance and power on steep climbs. Aside from the poles, hand-held water bottles are among the standard gear that runners carry regularly.

In this work, we propose a prototype that outputs navigational instruction through a haptic channel. Since this might be less intrusive, it could potentially allow users to subconsciously interact with the device while maintaining their main focus on running and the environment. There exists numerous examples of haptic navigation devices in research [2–7]. Primarily, these systems deploy vibration patterns, and few of them engage either shape change or skin drag. To the best of our knowledge, there exists no prior work that has investigated the combination of shape change and skin drag as a navigational aid under moderate physical load, e.g. while running. We present a haptic interaction device for running navigation, which could be integrated into typical trail running gear. This includes design, assembly and implementation of a hand-held prototype with the capability to provide haptic feedback through skin drag and shape change.

2 HAPTICPOLE: CONCEPT AND DESIGN

The first step in the design was to develop a set of navigation instructions that are suited for trail running. Typically, turn-by-turn navigation systems for sports provide instructions, such as "Turn Left", for the direction, combined with a numerical value, e.g. "in 350 m", for the distance. However, most of these instructions are either irrelevant or can be simplified for trail running, as typical crossings on trails are not as complex as their urban counterparts. We simplified the set of navigation instructions, which can be seen in Figure 3 based on informal interviews with experienced trail-runners at our university. It represents a reduced set of required instructions for directional guidance for turn-by-turn navigation in a trail running scenario. Similar to well-known turn-by-turn navigation instructions, continuing straight ahead is signaled by not displaying an instruction.

Slight Left	Left	Sharp Left	Slight Right	Right	Sharp Right	Wrong Turn/ U-Turn
1	2	3	4	5	6	7

Figure 3: Minimum set of required navigation instructions

In addition to these instructions, the distance to the next waypoint is also relevant. However, it is not necessary to provide exact distances. To enable reliable navigation, it is sufficient to transmit a relative distance to the waypoint or decision point as the distance becomes smaller. From a design perspective, it should be clearly identifiable when the decision point is reached and the next navigation instruction needs to be executed. Therefore, the two required states that need to be presented to the runner are *"approaching waypoint"* and *"waypoint reached"*.

From the design, multiple requirements for the actual prototype and its 3D models have been carefully considered. For ergonomic reasons, the overall size of the prototype had to be considered for the prototyping, as it needed to fit into the runners' hands comfortably. In particular, the diameter of the device is important to ensure a good grip. We tested several geometries and shapes: the round design had the advantage of not requiring a specific orientation, while feeling comfortable when grabbed.

If the diameter chosen was too large, the device could slip due to rapid arm movements and sweat during running. In addition, a robust hull, which can withstand some force and impact, is required, as runners might subconsciously grab too firmly. As a result of this, it is also essential that the chosen motors are able to produce a considerable amount of force, sufficiently strong to overcome a firm grip.

3 PROTOTYPE

All prototype parts were designed and modeled in Autodesk Fusion 360. The models of the parts were all created from scratch, except for the gears and threads which came from Fusion 360's catalog and were adapted to fit the given needs. We settled on the final prototype design that can be seen in Figure 1. This overview shows all the model parts without the electrical components and circuitry, except for the motors.

Over the course of modeling and testing all those parts, several necessary and some optional improvements became evident, resulting in redesigns of the affected parts. In the first redesign, almost all connection points between the parts were tightened, as the tolerances were too high. Specifically, the guidance for the *cylinder* through the *top plate* had to be improved. The *threaded rod* which allows for the extrusion of the *cylinder* via a stepper motor also had to be extended. In early iterations we also observed excessive heat generation from the motors, which led to the addition of ventilation holes that can be seen in the *top plate* and the *base plate*. The prototype can be split into two halves, where the *lower hull* contains a locking mechanism. It also contains a mount for the motor that will drive the *spur gear* for the *ring*. The electronics are connected to the *internal walls*, which are connected to the *base plate* by the corresponding clips. The ring centered between the two halves has 36 tactile ridges on the outside to enable the skin drag interaction. The inside consists of an internal ring gear with 50 teeth to interface with the *spur gear*.

To provide the desired functionality, different electronic parts and components were tested. The below named components eventually were utilized due either to their capabilities or the specific requirements. For a micro-controller, we chose a DFRobot CurieNano, a mini version of an Arduino 101 board based on the Intel Curie module. It has the main feature of BLE communication in central mode, which makes it compatible with the BLE connect feature of common running apps such as Komoot. Additionally, the board also has an extremely small form factor, which made it well suited for this prototype. The software for it was written using the Arduino IDE. To control the device remotely, multiple Python programs were used from a PC connected via BLE.

For the stepper motors, we utilized two 5V bipolar stepper motors with integrated 100:1 reduction gear box. The gear box drastically amplifies torque. This resulted in a step angle of 18/100° / step, a minimum pull in torque of 0.5 Kgf-cm and a maximum lead out torque of 0.8 Kgf-cm. These motors were each driven by a Polulu DRV8834 stepper motor driver, which was chosen due to the small footprint and the low-voltage options. Additionally, we used a mini push-button switch for the automatic calibration process of the cylinder. The switch is activated when the endpoint of the linear cylinder movement is reached; the system can compensate for missed steps and guarantee consistent movement outputs. The whole system was powered by two standard 3.7V LiPo batteries. To ensure that the wires connecting these components did not get tangled up in the mechanical parts, we used heat-shrink tubing and glue to keep them in place.

As users might drop the device due to e.g. sweating during a run, an additional wrist strap was attached to prevent it from falling and breaking. Additionally, the wrist strap allows users to be more relaxed during use, as they do not have to worry about accidentally dropping the device. Figure 2 demonstrates the proper grip of the HapticPole and the final prototype.

4 CONCLUSION

In this work, we proposed a haptic navigation concept for trail running navigation featuring skin drag and shape change as an unobtrusive haptic feedback modality, potentially enabling lower mental load during use. Based on this, we prototyped the HapticPole, a hand-held, self-contained, haptic trail running navigation device.

In future work, it will be used for an elicitation study to define the interaction patterns in a lab study. A possible next design iteration is to incorporate the proposed interaction with the concept of HapticPole into existing running gear, e.g. a handle of a running pole or a water bottle. However, additional impacts and vibrations have to be considered and tested in a follow-up field study. To allow for outdoor testing, it would be necessary to expand on the proof of concept and finalize the connection between GPS navigation apps (e.g. Komoot) and the prototype. This would enable a trail running study in the wild, which could provide valuable insights.

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